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USABILITY AND *VALIDITY* OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Monique Cruz Piderit

USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

by

Monique Cruz Piderit

Student number: 28020945

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Doctoral thesis submitted in fulfilment of the requirements of the degree

Philosophiae Doctor (Dietetics)

Department of Human Nutrition

Faculty of Health Sciences

University of Pretoria

Supervisor: Prof. Dr Friedeburg Anna Maria Wenhold

Co-Supervisor: Dr Zelda White

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DECLARATION AND ETHICS STATEMENT

I, Monique Cruz Piderit, declare that the thesis, which I hereby submit for the degree PhD Dietetics at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution, as confirmed by the Turnitin report.

I declare that partial sponsorship for this study was received by the Nestlé Nutrition Institute Africa. I declare that the Dairy Diary belongs to the Consumer Education Project of Milk SA. I declare that three R1 000 online vouchers were given to randomly selected respondents who participated in the usability sub-study and who voluntarily entered the draw.

Ethics Statement

I, Monique Cruz Piderit, obtained for the research described in this work, the applicable research ethics approval from the University of Pretoria (705/2018), North-West University, and University of the Free State. I declare that I have observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the policy guidelines for responsible research. Initial ethical approval was obtained in 2020, with subsequent reapplications in 2021, 2022 and 2023 (Annexure A).

Signed:  Date: 2023-12-27

ABSTRACT

USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

By Monique Cruz Piderit

Supervisor/Co-supervisor: Prof. Dr Friedeburg Anna Maria Wenhold/Dr Zelda White

Department: Human Nutrition, University of Pretoria

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Background

Paper-based dietary assessment tools such as food frequency questionnaires (FFQs) and especially dietary screeners are making way for versions that use technology. Amidst low intakes of dairy and dairy-related nutrients in South Africa and to increase public awareness thereof, this research aimed to develop and evaluate the usability of an application (app), namely the Dairy Diary, to screen for dairy intake in higher income South African adults. Thereafter, the screener was evaluated in terms of test-retest reliability and comparative validity.

Methods

Development and usability: In a consultative process, a dairy intake screener (Dairy Diary) was developed as an eight-item quantitative FFQ with four types of commonly consumed local dairy product, namely milk, maas (fermented milk), yoghurt, and cheese. For each dairy product, the usual frequency of consumption and portion size per eating occasion were scored (product serving score; PSS) and summed, resulting in a daily serving score (DSS) as a continuous variable with three risk classes, namely < 1 serving daily; 1 to < 2 servings daily; ≥ 2 servings daily. Digitalisation included product- and portion-specific graphics with linkage to risk class-relevant preliminary dairy-related guidance as part of a web-based mobile app. For the evaluation of the usability, the 26-item user-friendly end-user version of the Mobile Application Rating Scale (uMARS) was used in an online cross-sectional survey (Qualtrics, April 2020) of conveniently sampled adult respondents. Items were scored on a five-point Likert-

type scale resulting in three scores made up of six subscales. Descriptive statistics summarised the findings, with mean scores ≥ 3.0 considered acceptable.

Reliability and validity: In a diagnostic accuracy study, purposefully recruited undergraduate dietetics/nutrition student volunteers from three South African universities completed three non-consecutive days of weighed food records (reference standard) within a seven-day period (comparative validity), followed by two administrations, two weeks apart, of the screener (index test) (reliability). Dairy intake from the food records was converted to be comparable to dairy intake in the screener. For the reliability and validity assessment, statistical analyses included mean differences, paired t-tests and Pearson rank correlations for continuous data, and Kappa statistic for categorical data. For test-retest reliability, McNemar's test for symmetry was performed on categorised DSSs. For the validity assessment, agreement between the DSSs of the first administration of the Dairy Diary and mean DSSs of the three food records was verified with Bland–Altman plots. Sensitivity , specificity , predictive values, odds ratios and receiver operating characteristics (ROC) were used to quantify the diagnostic ability of the categorised DSSs of the Dairy Diary.

Results

Development and usability: From 1 102 respondents, 703 (64%; 81% female; mean age 29.8 ± 11.0 years) were retained for analysis. The uMARS mean app quality score (objective) (3.9 ± 0.85), app subjective quality score (3.5 ± 0.77), app-specific score (3.6 ± 0.94), and the additional question on the e-portion (4.3 ± 0.78) exceeded minimum acceptability. For the subscales, the mean score for aesthetics was the highest (4.4 ± 0.82), followed by information (4.3 ± 0.90) and functionality (4.0 ± 1.33). Engagement scored the lowest (3.0 ± 1.55).

Reliability and validity: Participants included a purposefully recruited sample of 79 (100% female; mean age: 21.6 ± 3.8 years). For reliability, mean PSSs and DSSs did not differ significantly ($P > 0.05$) between the screener administrations. Mean PSSs were strongly correlated: milk ($r = 0.69$; $P < 0.001$), maas (fermented milk) ($r = 0.72$; $P < 0.001$), yoghurt ($r = 0.71$; $P < 0.001$), cheese ($r = 0.74$; $P < 0.001$). For DSSs, Kappa was moderate ($\kappa = 0.45$; $P < 0.001$). Non-agreeing responses suggest symmetry ($P = 0.334$). For validity, the PSSs of the screener and food records were moderately correlated [milk ($r = 0.30$; $P = 0.0129$), yoghurt

(*r* = 0.38; P < 0.001), cheese (*r* = 0.38; P < 0.001)], with κ = 0.31 (P = 0.006) for DSS. Bland–Altman analyses showed acceptable agreement for DSSs (bias: −0.49; 95%CI: -0.7 to −0.3). Categorised DSSs had high sensitivity (81.4%) and positive predictive value (93.4%), yet low specificity (55.6%) and negative predictive value (27.8%). The area under the ROC curve (0.7) was acceptable.

Conclusion

The Dairy Diary is a user-friendly screener for dairy intake, with high aesthetic appeal and low engagement. Furthermore, it is test-retest reliable and has moderate potential to be a comparatively valid tool to screen for dairy intake of groups of higher income South Africans.

Keywords

Dietary screener; dairy intake screener; usability; validity; reliability**.**

DEDICATION

For Joshua and Daniel,

Because my boys deserve a mama that they can always be proud of.

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Once upon a time, God placed a dream in a little girl's heart. My heartfelt thanks to all who contributed to making that little girl's PhD dream a reality.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ADSA	Association of Dietetics in South Africa
app	Application
AQEL	App Quality Evaluation
BMI	Body Mass Index
CEP	Consumer Education Project
CI	Confidence Interval
DD1	First Administration of the Dairy Diary
DD2	Second Administration of the Dairy Diary
DHQ	Dietary History Questionnaire
DSS	Daily Serving Score
FFQ	Food Frequency Questionnaire
FR	Food Records
ILSI	International Life Sciences Institute
LOA	Limit of Agreement
LSM	Living Standards Measure
(u)MARS	(User-friendly version of the) Mobile App Rating Scale
(q)FFQ	(quantitative) Food Frequency Questionnaire
NNIA	Nestlé Nutrition institute of Africa
NPV	Negative Predictive Value
NWU	North-West University
PPV	Positive Predictive Value
PSS	Product Serving Score

ROC	Receiver Operating Characteristic
SAMPRO	South African Milk Processors' Organisation
SD	Standard Deviation
Se	Sensitivity
Sp	Specificity
STARD	Standards for Reporting Diagnostic Accuracy Studies
THESIS	Transparency, Health Content, Excellent Technical Content, Security/Privacy, Issues of Usability and Subjective Ratings
UFS	University of the Free State
UP	University of Pretoria

1 CHAPTER 1: INTRODUCTION

1.1 Background and Rationale of the Study

The assessment of dietary intake is a crucial aspect of dietary surveillance and intervention.[1] Common dietary assessment methods include food records, 24-hour dietary recalls, and food frequency questionnaires (FFQs). However, the comprehensive assessment of an individual's dietary intake is notoriously challenged and subject to random and systematic measurement errors.[2] Moreover, the tools developed for this purpose may be costly, time-consuming, and burdensome, for researcher and participant alike.

A potentially more cost-effective and less laborious approach uses shorter dietary assessment tools, known as dietary screeners. When administered, dietary screeners identify individuals requiring a more comprehensive and detailed dietary assessment for timely intervention by a registered dietitian.[3-5] A dietary screener may take the structure of an FFQ, with technology-based versions in the form of web- and mobile-based applications (apps).[6,7] Gaining favour over traditional (paper-based) versions, health-based mobile apps have been shown to be an effective strategy for health promotion.[8,9] Furthermore, the development of innovative mobile app-based dietary assessment tools has been reported.[10]

The South African food-based dietary guideline for dairy recommends to "Have milk, maas* and yoghurt every day"[11] yet dairy intakes are low in South Africa: 0.4 – 0.5 servings per day.[12] In light of strong consistent evidence suggesting the positive role of dairy in managing non-communicable diseases,[13-16] contributing to meeting gap nutrient intakes,[17] and being a surrogate marker for diets higher in nutritional quality,[17-19] increasing dairy consumption may help close the gaps between current intakes and recommendations.

Internationally, dietary screeners are available to screen for dairy intake. These have been developed and/or validated for populations in North America,[20-23] Australia,[24-27] Asia,[28,29] the Netherlands,[20,24,25,30,31] and Poland.[32] Some dietary screeners listed are technology-based.[20,22,25,31]

*Maas is the vernacular term for fermented milk in South Africa.

There is an ever-increasing trend to access health- and nutrition-related information via mobile apps,[33,34] with indications that individuals are within arm's reach of their mobile phone 50% of the time.[35] In South Africa, mobile app downloads are high[36] and qualitative research has shown a preference of the mobile user for apps that are quick and easy to administer and that increase the awareness of food intake.[37] The development and uptake of mobile technology offers significant opportunity for affecting health behaviour and delivering nutrition intervention.[38] There are calls for nutrition professionals to be involved in the development of nutrition-related mobile apps.[23,39]

Validation studies on FFQs as dietary screeners are widely available in South Africa,[42,43] Morocco,[44] Germany,[45] France,[46] Spain,[47] the Netherlands,[31,48] the Mediterranean,[49,50] North America,[51] South America,[52,53] Australia,[54] New Zealand,[55] Asia,[56-60] and the Middle East.[61,62]

More specific to dairy intake screeners, a review of the literature indicates that a dairy intake screener does not exist in South(ern) Africa. Considering low dairy intakes and the growing trend of smartphone usage, a technology-based dairy intake screener would be a novel and unique contribution to the field of nutrition and dietetics in South Africa. Screening for dairy intake may initiate, motivate, and drive behaviour change by raising awareness of low dairy intakes. Such a contribution may further provide opportunity to target dairy-based nutrition education, supporting the mandate of initiatives such as the Consumer Education Project (CEP) of the South African Milk Processors' Organisation,[63] funded by government and industry.

Thus, the Dairy Diary (available at https://dairygivesyougo.co.za/dairy-diary/) was developed as a dairy intake screener[64] in the form of a web-based mobile app to screen for locally consumed dairy products in South Africa, namely milk, maas, yoghurt, and cheese. The name of the screener, the Dairy Diary, as titled by the CEP of Milk SA, bares no reference to the screener format as a food diary, a term commonly used in dietary assessment as a synonym for food record. Rather the Dairy Diary has a FFQ format, with the alliteration of the title adding appeal to the consumer target group for which it was developed.

Ideally, such a tool should be easy and quick to use (usable) and with high sensitivity and high specificity to correctly detect low dairy intake risk (valid). If valid, the screener may contribute

to the quick screening of dairy intake in a country with the increase of dairy intake being a priority. Accordingly, this study aimed to evaluate the usability and validity (test-retest reliability and comparative validity) of the Dairy Diary in South African adults.

1.2 Research Question

Is the Dairy Diary a usable and valid tool to screen for dairy intake in South African adults?

1.3 Aim and Objectives

A schematic representation of the research study is illustrated in Figure 1.1. Aligned to this, the aim and objectives of the sub-studies are presented.

1.3.1 Aim

The aim of this study was to evaluate the usability and validity (test-retest reliability and comparative validity) of the Dairy Diary to screen for dairy intake in South African adults.

1.3.2 Objectives

The objectives of this research were as follows:

1. To report on the development of the Dairy Diary using the five-step best practice guidelines recommended by the International Life Sciences Institute (ILSI) Europe Dietary Intake and Exposure Task Force for reporting on technologically based dietary assessment tools.[65]
2. To evaluate the usability of the Dairy Diary in South African adults (consumers and nutrition professionals) using uMARS.[66]
3. To determine the test-retest reliability of the Dairy Diary among dietetics/nutrition students with two administrations of the screener on an individual level
4. To determine the test-retest reliability of the Dairy Diary among dietetics/nutrition students with two administrations of the screener on a group level.
5. To determine the comparative validity of the Dairy Diary (i.e. index test) against three-day weighed food records (i.e. reference standard) among dietetics/nutrition students.

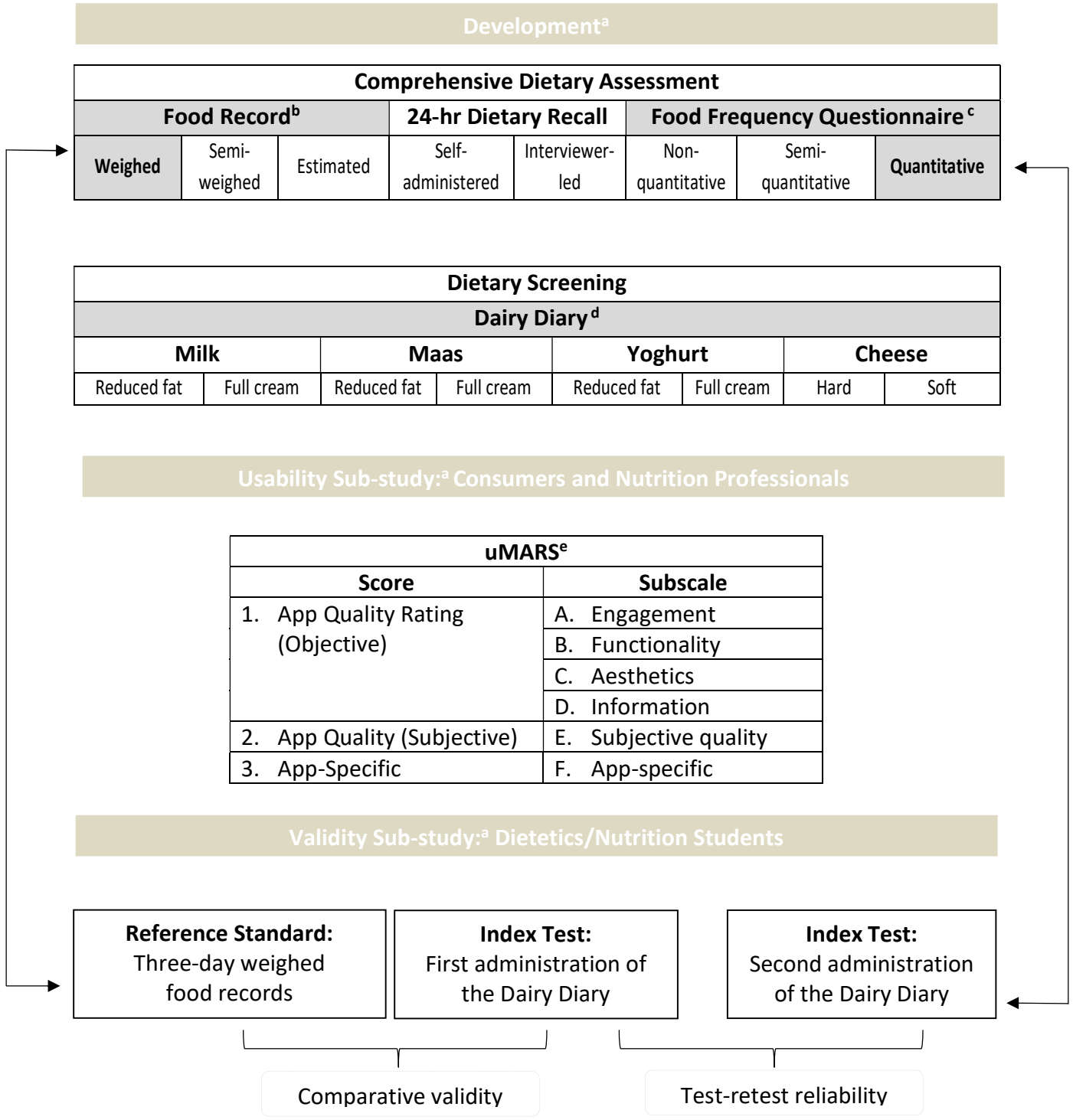

Figure 1.1: Framework for the usability sub-study and validity sub-study

a The three phases of the Dairy Diary are shown: development, usability sub-study and validity sub-study (test-retest reliability and comparative validity).

b The weighed food recorded was the reference standard.

c An FFQ in a quantitative format was the index test.

d The Dairy Diary is an eight-item quantitative FFQ in the form of a web-based mobile app. Reduced fat included low fat (semi-skimmed) and non-fat (skimmed) milk.

e The user-friendly version of the Mobile Application Rating Scale (uMARS) was used to evaluate the usability of the Dairy Diary.

The first and second objectives (usability sub-study) were addressed in the published article entitled, "The Development and Usability of a Web-based Mobile Application as a Dairy Intake Screener for South African Adults",[67] reproduced in Chapter 3. The third and fourth objectives (validity sub-study) were addressed in the manuscript entitled, "Dairy Intake Screener as a Web-based Application is Reliable and Valid", submitted to a scientific journal and under peer review. Refer to Chapter 4.

1.4 Inclusion and Exclusion Criteria

Table 1.1 shows the inclusion and exclusion criteria of the study, which were the same for both sub-studies. The LSM is a widely used socioeconomic segmentation tool in South Africa for classifying consumers independent of race/ethnicity, sex, age, or any other variable. The CEP identifies a higher LSM as a target group for consumer education on increasing dairy intake, informed by the high cost of dairy in South Africa, with high data costs for use of a technology-based tool.

Table 1.1: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Age	≥ 19 years; ≤ 65 years	< 18 years; > 66 years
Internet and smartphone and/or computer	Access to internet and smartphone and/or computer	No access to internet and smartphone and/or computer
Living Standards Measure (LSM)	> 8	< 7

1.5 Definition of Key Terms

Table 1.2 summarises the theoretical and operational definitions of terms (listed alphabetically) used in this study.

Table 1.2: Theoretical and operational definitions used in this study

Term	Theoretical definition	Operational definition for this study
Comparative validity	Assessed by comparing an *index test* with a *reference standard* where the *reference standard* has a greater degree of demonstrated validity, even if not an exact measure.[2]	The first administration of the Dairy Diary (i.e. *index test*) compared with the mean dairy intake according to three-day weighed food records (i.e. *reference standard*). For validity analyses, the agreement between the *daily serving score* and *product serving scores* of the first administration of the Dairy Diary compared with the corresponding scores of the three food records was determined.
Daily serving score (DSS)	The *daily serving score* was the sum of the four *product serving scores*, classified into three risk classes, namely: < 1 serving daily, 1 to < 2 servings daily, and ≥ 2 servings per day). See *product serving score*.	
Diagnostic accuracy study	A study investigating the degree of agreement between information from an *index test* and the *reference standard.*[6]	The degree of agreement between information from the Dairy Diary and the weighed food records. Statistical tests included parametric analyses assessing the strength of association between the Dairy Diary and food records using mean differences, t-tests, Pearson rank correlation (continuous data, i.e. *product serving score* and *daily serving score*) and Kappa statistics for categorised data (i.e. *daily serving score*). Sensitivity, specificity, predictive values, odds ratios, and receiver operating characteristics (ROC) were used to quantify the diagnostic ability of the categorised *daily serving scores* of the Dairy Diary.

Term	Theoretical definition	Operational definition for this study
Dietary assessment	Part of nutrition assessment: the science and art of evaluating dietary intake in individuals or groups.[4] *Dietary assessment* methods include 24-hour dietary recalls, food records, and *food frequency questionnaires*.	Three-day weighed food records (non-consecutive days, including one weekend day) were the reference *dietary assessment* method.
Dietary screening	Nutrition screening triggers entry into the nutrition care process.[4] *Dietary screening* is part of nutrition screening, achieved with quick and efficient screening tools, which may be in the form of a *food frequency questionnaire*.	The screening for dairy intake by means of the web-based app Dairy Diary (https://www.dairygivesyougo.co.za/dairy-diary/).
Food frequency questionnaire (FFQ)	A retrospective dietary assessment method to assess how often *(frequency)* food items from a predetermined *food list* are usually consumed within a specified *reference period.*[68] In the quantitative version (*quantitative food frequency questionnaires*), *portion sizes* of the foods are also determined.	The basic format for the Dairy Diary is a quantitative *food frequency questionnaire*. For the *reference period,* participants were prompted to consider habitual dietary intake of dairy products, usually consumed as a snack or meal, eaten at or away from home and/or eaten alone or as part of a meal over the previous month. The *food list* included four commonly consumed dairy products in South Africa (milk, maas, yoghurt, and cheese). *Frequency* was assessed in four frequency categories: never, per day (0–3 times), per week (1–6 times), or per month (1–3 times). *Portion sizes* for each dairy product were assessed as little, medium, or lots, defined as 50%, 75%, and 100% or more of a reference serving, respectively.
Frequency score	For each dairy product, the *frequency* (number of times) of consumption was assessed in four frequency categories: never, per day (0–3 times), per week (1–6 times), or per month (1–3 times). To score daily intake amounts, the *frequency* per day was defined by a factor of 1 (i.e. if the user indicated eating cheese once a day, the factor is 1/1). To score weekly amounts, the *frequency* per week was defined by a factor of 7 (i.e. if the user indicated drinking milk three times per week, the factor is 3/7). To score monthly amounts,	

Term	Theoretical definition	Operational definition for this study
	the *frequency* per month was defined by a factor of 30.417: the average number of days per month in a calendar year (i.e. if the user reported consuming maas twice per month, the factor is 2/30.417).	
Index test	The test under evaluation.[69]	Dairy Diary is the *index test.*
Living standards measure (LSM)	Segmentation tool to segment the South African market, cutting across race, gender, age or any other variable used to categorise people.[70]	Higher *living standards measure* refers to those participants with a *living standards measure* ≥ 8 as calculated by the Eighty20[70] *living standards measure* calculator.
mHealth	The use of mobile and wireless technologies to support the achievement of health objectives, including text messages, sensors, wearable devices, and mobile apps.[71]	*mHealth* refers to the web-based mobile app, the Dairy Diary.
Negative likelihood ratio (1 − Sn)/Sp	Measure of the usefulness of a diagnostic test for the presence of a condition or disease; indicates the odds of the test yielding a false negative relative to yielding a true negative among those without the condition or disease.[2]	In this study, lower values of the negative likelihood ratio indicated that the Dairy Diary is effective at ruling out low dairy intakes (i.e. ≤ 2 servings of dairy per day).
Positive likelihood ratio (1 − Sn)/Sp	Measure of the usefulness of a diagnostic test for the presence of a particular condition or disease; indicates the odds of the test yielding a true positive among those with the condition or disease relative to yielding a false positive among those without the condition or disease.[2]	In this study, higher values of the positive likelihood ratio indicated that Dairy Screener is effective at establishing low dairy intakes (i.e. ≤ 2 servings of dairy per day).
Positive predictive value (PPV) (Tp/Tp + Fp) × 100	The measure of the probability of a given case having a condition or disease if the result of a diagnostic test for the presence of a particular condition or disease is positive.[2]	The *positive predictive value* of this study suggests the percentage of those participants with a positive test, i.e. fewer than two servings of dairy per day.

Term	Theoretical definition	Operational definition for this study
Product serving score (PSS)	For the food records and the Dairy Diary, a *product serving score* was calculated for each dairy product by multiplying the *frequency score* by the *portion score.* For both, the *daily serving score* is the sum of the four *product serving scores*.	
Reference standard	The best available method for establishing the presence or absence of a target condition.[69]	The *reference standard* was three-day weighed food records. For each food record for each day, raw data on portion size of dairy product consumed was captured (Microsoft Excel) and quantities of dairy products converted into daily serving equivalents using a reference serving (250 mL for milk, 250 mL for maas, 200 mL for yoghurt, 30 g for hard cheese, and 60 mL for soft cheese; i.e. amounts containing 300 mg of calcium).[72] The daily serving equivalents were summed to calculate the food record *daily serving score*, repeated for each food records. The mean of the *daily serving score* of the three food records were calculated and categorised.
Serving score	Portion size of the Dairy Diary consumed per eating occasion for each dairy product, as shown by text and quantifiable graphics indicated as little, medium, or lots, defined as 50%, 75%, and 100% or more of a reference serving, respectively.	
Test-retest reliability	The extent to which repeated measurements of the same concept for an individual will be similar.[2] The reliability of *food frequency questionnaire*s can be assessed by administering the *food frequency questionnaire* at two points in time to the same group and assessing the association.[73]	*Test-retest reliability* was assessed in the dietetics/nutrition students by administering the Dairy Diary twice, two weeks apart. For the reliability assessment, the mean *product serving score* and *daily serving score* were assessed using Pearson rank correlation (continuous data, i.e. *daily serving score* and *product serving score*) and strength of agreement using Kappa values (categorical data, i.e. *daily serving score*).
Usability	The extent to which a product can be used by specified users to achieve the specified goals with effectiveness, efficiency, and satisfaction in specified context of use.[74]	*Usability* was evaluated in respondents using *uMARS.* The minimum mean acceptable score was ≥ 3.0.[75]

Term	Theoretical definition	Operational definition for this study
Sensitivity (Sn) (Tp/[Tp + Fn]) × 100	The extent to which a diagnostic test correctly identifies those who have a particular condition or disease.[2]	*Sensitivity* is the ability of the Dairy Diary to correctly identify participants consuming fewer than two servings of dairy per day. The greater the *sensitivity*, the more likely that the Dairy Diary will identify a person with low dairy intake.
Specificity (Sp) (Tn/[Fp + Tn]) × 100)	The extent to which a diagnostic test correctly identifies those who do not have a particular condition or disease.[2]	*Specificity* is the ability of the Dairy Diary to correctly identify those who consume more than two servings of dairy per day.
True positive (Tp)	Result of a test for the presence of a disease or condition indicating that the disease or condition is present for a given subject in cases when it really is present.[2]	*True positives* refer to the number of participants classified by the Dairy Diary as consuming fewer than two servings per day.
True negative (Tn)	Result of a test for the presence of a disease or condition indicating that the disease or condition is present for a given subject in cases when it really is not present.[2]	*True negative* refers to the number of participants correctly classified by the Dairy Diary as consuming more than two servings of dairy per day.
Validation	Process of determining whether a measure or indicator is suitable for providing useful analytical measurement for a given purpose and context.[1]	The process of comparing the dairy intake by means of the Dairy Diary in South African adults against the intake according to three-day weighed food records. See *diagnostic accuracy study.*
Web-based mobile application (app)	Mobile apps are software applications that can be executed (run) on a mobile platform (i.e. handheld, commercial off-the-shelf computing platform, with or without wireless connectivity) or a web-based software app tailored to a mobile platform but executed on a server.[76]	The *web-based mobile app* will be used to define the Dairy Diary, which can be executed (run) as both a *web- and mobile-based application* designed for use on a smartphone and/or internet-connected device, such as a tablet, PC, or web page on a smartphone.

Tn: True negative; Tn: True positive; Fn: False negative; Fp: False positive.

1.6 Delimitations, Limitations and Assumptions

For the usability sub-study:

- The population (consumers and nutrition professionals) was limited to a convenience sample of South African adult volunteer respondents with access to computer and/or smartphone and internet.
- The assessment of usability of the Dairy Diary was delimited to an evaluation using uMARS.[66]
- It was assumed that the respondents understood portion sizes specified in the Dairy Diary. More so, it was assumed that portion sizes expressed as drawings in an e-format were understood.

For the validity sub-study:

- It was assumed that the dietetics/nutrition student population is reflective of the consumer population. It is assumed that the reliability and validity tested in dietetics/ nutrition students will reflect the reliability and validity of the Dairy Diary in the target population of the screener.
- The validation of the Dairy Diary was limited to test-retest reliability and comparative validity.
- For test-retest reliability, it was assumed that changes in diet would not occur between the two administrations of the Dairy Diary. The interval between administrations was two weeks.
- It was assumed that there was no learning spillover between the two administrations of the Dairy Diary. For this, the interval between administrations was two weeks[73] and participants were blinded to the DSS in each administration of the Dairy Diary.
- It was assumed that the non-consecutive three-day weighed food records that included two weekdays and one weekend day represented usual dietary intake.

For the usability and validity sub-studies:

- The four dairy products (milk, maas, yoghurt and cheese) in the Dairy Diary were assumed representative of the majority of dairy intake of South African adults.
- It was assumed that the usual intake of dairy is not seasonal.
- It was assumed that all participant and respondent answers to the questionnaire were honest.

1.7 Ethical Approval

Ethical approval was obtained from the Faculty of Health Sciences, University of Pretoria Research Ethics Committee (705/2018) and North-West University Health Research Ethics Committee (NWU-00461–19-A1). A letter of approval was obtained from the Department of Nutrition and Dietetics as per the requirements of the University of the Free State (Annexure A).

1.8 Description of Study and General Methodology

A critical analysis of literature on dietary assessment and available tools to screen for dairy and/or calcium intake was conducted. The literature search, originally conducted in July 2018 further updated in August 2022 and June 2023, was conducted via Google Scholar, PubMED, and the University of Pretoria Library. Search criteria included keywords such as “screening tool”, “screener”, “dairy screening tool”, “dairy intake screener”, “usability”, “validity of dietary screener”, and “FFQ and validation”. No relevant web-based dairy intake screener was identified, necessitating the development of a local tool. Thus, the Dairy Diary was developed to identify the risk of low dairy intakes.

The development of the Dairy Diary was commissioned by the CEP of Milk SA in November 2017 as a standalone project in which the candidate was involved as a, ad-hoc member of the technical advisory committee of the CEP. As such, the development of the screener did not warrant focus within the objectives of this study and was reported on using best practice guidelines for reporting on technologically based tools. Though the screener was initiated by industry, the structure was informed by the South African food-based dietary guidelines and

recommendations from similar studies, upon which the content and interpretation of a South African dairy intake screener were compiled. A food-based approach focusing on milk, maas, yoghurt and cheese was identified, using an amount containing 300 mg of calcium as the reference serving size of the dairy products. Similar to other traditional (paper-based) versions of screeners, the quantitative FFQ was chosen as a basic format, with a scoring system theoretically calculating dairy intake. Graphic enhancement, interactivity, and preliminary guidance (based on respondent DSS) and linkage to existing information from the CEP website was added. The draft was reviewed and revised by a working group of nutrition professionals knowledgeable in dietary assessment and dairy nutrition. Software developers translated the content into a web-based app. Ongoing refinement took place.

Technology-based dietary screeners are assessed in terms of usability. A usable tool is more likely to create engagement and interaction by the respondent. The usability sub-study was an online cross-sectional survey in a conveniently identified population of adult respondents (consumers and nutrition professionals). To evaluate the Dairy Diary, uMARS[66] was used and the summary statistics were interpreted in relation to published minimum acceptability scores.[75] The mean time to completion of the usability study was 25.5 minutes. The estimated time to complete the Dairy Diary is 5 minutes.

For the validation sub-study, the Dairy Diary (i.e. index test) was assessed in terms of test-retest reliability and comparative validity in a sample of volunteering dietetics/nutrition students from three different South African universities. Weighed food records were the reference standard. Participants completed three non-consecutive days of weighed food records within a seven-day period. This was followed by two administrations of the Dairy Diary two weeks apart. The reference standard was scored to enable comparison with corresponding scores in the index test.

1.9 Layout of the Thesis

This thesis is presented in line with the guidelines for presentation of the Faculty of Health Sciences PhD in a publication format. It comprises a general introduction, literature review and two manuscripts, with a final general discussion, recommendations and concluding remarks. Detailed and comprehensive accounts of the methodology of each sub-study are

presented in Chapter 3 (Development and Usability of a Web-based Mobile Application as a Dairy Intake Screener for South African Adults)[67] and Chapter 4 (Dairy Intake Screener as a Web-based Application is Reliable and Valid) *(*submitted).

Each chapter has its own reference section. Aligned to journal specifications, the results chapters, presented in the manuscript/publication format, are formatted as per the target journal. The reference list for this thesis is presented in a combined format of Vancouver (Chapters 1, 2 and 5) and Harvard (Chapter 3 and 4) referencing styles.

1.10 Conclusion

The Dairy Diary is a dairy intake screener with an FFQ format, developed as a web-based mobile app. It includes four commonly consumed dairy products in South Africa (reduced fat and full cream): milk, maas (fermented milk), yoghurt, and cheese, each in high fat and reduced fat version, resulting in an eight-item screener. The objectives of this study were to assess the usability (Chapter 3) of the Dairy Diary in consumers and nutrition professionals, as well as assess the comparative validity and test-retest reliability (Chapter 4) in a sample of dietetics/ nutrition students assumed to reflect higher income South African adults.

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2 CHAPTER 2: LITERATURE REVIEW

This study aimed to assess the usability and validity (comparative validity and test-retest reliability) of the Dairy Diary, an eight-item dairy intake screener with an FFQ format, which was developed as a web-based mobile app. Accordingly, this chapter briefly introduces the role of dairy in health, with a main focus on a review of available literature on dietary screening, the evaluation of technology-based dietary screeners, the availability of dairy intake screeners, and the validation thereof.

2.1 The Role of Dairy in Health

The totality of available evidence supports that dairy products play a significant role in a healthy and balanced diet to protect against chronic diseases, including cardiovascular disease,[1,2,3] hypertension,[4,5] metabolic syndrome,[6,7] and type II diabetes mellitus.[8.9] Dairy products contribute to meeting nutrient recommendations[10] with consensus that dairy intake may be a surrogate marker of diets higher in nutritional quality.[1,10-13] Dairy is a good source of high-quality protein, potassium, magnesium, phosphorus, zinc, selenium, vitamin A, riboflavin, thiamine, vitamin B12, and vitamin D (when fortified)[10] and contributes considerably to dietary calcium intake.[14]

Two to three servings of dairy per day are recommended.[10] Clear differences in dairy consumption globally are evident with Dutch[15] and Irish[16] populations having far greater dairy intakes than Brazil,[17] Mexico,[18] and Australia.[19] In South Africa, dairy is the most commonly deficient food group alongside fruit and vegetables.[20]

2.2 Dietary Assessment and Dietary Screening

In literature and in practice, it is common for the terms “dietary assessment” and “dietary screening” to be used interchangeably.[21,22] However, while complementary, dietary assessment and dietary screening serve distinct roles, with dietary assessment concluding a nutrition diagnosis and dietary screening predicting the probability that a more detailed nutrition assessment is warranted.[22,23]

2.2.1 Dietary assessment

Dietary assessment forms part of nutrition assessment: data from dietary, laboratory, anthropometric and clinical studies are interpreted to determine the nutritional status of an individual or populations, as influenced by the intake and utilisation of nutrients.[22] Accurate assessment of dietary intake is essential in nutrition research, with many dietary assessment methods available, such as food records, 24-hour dietary recalls, and FFQs.

The choice of dietary assessment method used is dependent on the study design, sample size, and research question,[24] with each subject to various strengths and weaknesses.

2.2.1.1 Food records

Food records document the types and amounts of foods and beverages consumed over a period.[24,25] Food records collect self-reported intake at the time of eating, thus minimising reliance on the individual's memory.[24,25]

Depending on the aim of the research, a food record may include more detailed information, such as food preparation methods, the ingredients of composite/mixed dishes, recipes, and the brand name of food products.[25] With estimated food records, the respondent estimates intake using portion sizes and/or household measures. In weighed food records, there is reduced risk of portion size estimation error.[26] Weighed food is usually measured with kitchen scales or household measures, such as cups. Portion sizes may be estimated with reference to standard household measures or using two- or three-dimensional portion size estimation aids, such as food models or photographs.[25]

Ideally, the number of days that food is recorded for should be long enough to gather reliable information on usual food intake with consideration for poor compliance if the period is too long.[25] Thus, usually one to seven days on non-consecutive days is preferred.[24,26]

The food record is vulnerable to underreporting and high dropout rates requiring literate and co-operative respondents.[25,26] There is a considerable risk of altering diet because of the burden of recording complex foods.[25,26] However, given the quality of dietary data collected

in food records, this dietary assessment method is often used as a reference standard for validation studies.[25]

2.2.1.2 24-hour dietary recall

The 24-hour dietary recall method requires individuals to recall the specific foods and amounts eaten in the previous 24 hours. It is a subjective, retrospective method (face-to-face or telephonic interviews) administered by a trained interviewer.[27] Self-administered web-based versions also exist.[28] Information can be collected via open or closed questions and multiple (2–5 day) 24-hour dietary recalls done by the same respondents over several days are needed to establish usual intake.

Advantages include ease of administration, high response rate, detailed intake data, and the ability to administer to low literacy populations with relatively small respondent burden.[27,28] Limitations include possible recall bias, the need for a trained interviewer, the potential for interviewer bias, expense, and the process being time-consuming as multiple days are required to assess usual intake.[27] Underreporting (due to factors such as obesity, gender, social desirability, hunger, education, literacy, perceived health status, age, and race/ethnicity)[29] and high day-to-day dietary variability may mean the information obtained does not reflect usual diet.[26,28] There may further be possible changes to diet with repeated measures.[27]

2.2.1.3 Food frequency questionnaire

The FFQ is ubiquitous in research as a practical and cost-effective dietary assessment method for large-scale studies. The FFQ is a retrospective dietary assessment method where individuals report usual food consumption and frequency from a concise and structured food list as relevant to the study objective. Respondents indicate the number of times a day, week, month or year food is consumed.[30]

The main components of an FFQ are the food list and frequency of consumption. In a non-quantitative FFQ, portion sizes are not indicated and the number of times that the respondent consumes the food of interest is recorded. In a quantitative FFQ, portion sizes are included.[30]

Studies suggest that quantitative FFQs may have more scientific rigor than non-quantitative versions.[31] The general strengths and limitations of the FFQ are summarised in Table 2.1.

Table 2.1: Strengths and limitations of FFQs[27,30]

Strengths	Limitations
▪ Assesses usual dietary intake simply. ▪ Self-administered. ▪ Does not require well-trained interviewers. ▪ Low to moderate respondent burden, depending on the demographics and context. ▪ Better representation of usual dietary patterns. ▪ Viable for automated processing. ▪ Improved quality of data collection when web-based. ▪ Cost-effective for large-scale studies. ▪ Suitable for epidemiological studies.	▪ Requires literacy, numerative and cognitive skills if not interviewer-led. ▪ Inaccuracies from incomplete food listings, errors in portion estimations and frequency. ▪ Frequency of consumption and portion size may not represent usual intake. ▪ High respondent burden. ▪ Overestimation is common for foods eaten less frequently. ▪ Specific to study group, research aims and/or country. ▪ Uses closed-ended questionnaire. ▪ Low accuracy (recall bias). ▪ Requires accurate evaluation of developed questionnaires.

2.2.2 Dietary screening

Screening refers to the process of identifying an individual who is malnourished or at risk of malnutrition to determine whether a detailed nutrition assessment is needed.[32] More specifically, nutrition screening is the process of identifying patients, clients or groups who may have a nutrition diagnosis and could benefit from nutrition assessment and intervention by a registered dietitian.[22] Nutrition screening can be done on the whole population or be targeted to a specific subgroup of the population or select individuals.[32,33]

As described in the nutrition care process (a standardised process to identify nutrition-related problems and provide appropriate intervention), nutrition screening is separate from and different to nutrition assessment.[22,34] Nutrition screening precedes nutritional assessment and serves as a trigger into the nutrition care process for comprehensive dietary assessment and the continued gathering of information initiated by screening.[22,34,35] Thus, compared with dietary assessment, the information collected in dietary screening is less in-depth.

Well-known nutrition screeners include the Subjective Global Assessment,[36] Nutritional Risk Index,[37] Mini Nutritional Assessment,[38] Malnutrition Screening Tool,[39] and Short Nutritional Assessment Questionnaire.[40] As per recommendations by Skipper et al,[33] key considerations for nutrition screening are as follows:

- Nutrition screening should be conducted in any appropriate setting.
- Nutrition screening tools should be quick, easy to use, valid and reliable for the patient population or setting.
- Nutrition screening tools and parameters are established by registered dietitians, but the screening process may be conducted by other trained healthcare professionals.
- Nutrition screening and rescreening should occur with an appropriate period for the setting.

2.2.2.1 Dietary screeners

More specifically, dietary screening forms part of nutrition screening. While not considered a substitute for a more complete measure of usual dietary intake, dietary screening may be considered when assessment of total diet is not needed, or if financial and time constraints are applicable.[23,41] The process of dietary screening utilises quick and efficient screening tools, also known as dietary screeners.[35,42]

2.2.2.2 Food frequency questionnaires as dietary screeners

Though multiple dietary screener formats exist, a dietary screening tool may be in the format of an FFQ, which rely on generic memory (as opposed to specific memory) to complete.[24] As described above for FFQs, similar strengths and limitations exist for dietary screeners in an FFQ format.

Studies have been published on the validity of FFQs as screeners for use in specific countries and regions such as South Africa,[43,44] Morocco,[45] Germany,[46] France,[47] Spain,[48] the Netherlands,[49] Belgian,[50] the Mediterranean,[51,52] North America,[53] South America,[54,55] Australia,[56] New Zealand,[57] Asia,[58-62] and the Middle East.[63,64]

Dietary screeners may focus on population groups such as children,[65,66] adolescents,[67] pregnant women,[68] the elderly,[69-71] or athletes.[72] Dietary screeners may also focus on disease-specific conditions.[73,74] Dietary screeners may further focus on dietary patterns such as the whole diet,[75] specific food groups (e.g. legumes,[76] fruit and vegetables,[77-83] wholegrain cereals)[84] or individual nutrients (e.g. phytoestrogens,[85] anti-oxidants,[86] polyunsaturated fatty acids,[87] or sodium.[44]). More specific to calcium, several dietary screeners have been developed.[70,88-99] Reviews of calcium and/or dairy screeners for children and adolescents[100] and adults[101] are available.

Regarding dairy, international dietary screeners that include dairy have been developed and validated for use in adults in the Netherlands,[89,102,103] Australia,[104,105] and the United States.[106] most of which focus on the total diet and none which focus on dairy specifically. To the best of the researcher's knowledge, no dietary screeners to screen for dairy intake have been developed and/or validated for use by South African adults.

2.3 Dietary Screening and Technology

There is growing interest in the potential for technology-based health- and nutrition-related interventions on an individual level.[107,108] For research purposes, the utilisation of modern technologies for measuring dietary intake in national nutrition surveys has been proposed, posing a possible effective strategy to maximise respondent rates and minimise non-response bias.[109,110]

Technology-based dietary screening and dietary assessment tools may take the form of a web- or mobile-based app. Mobile apps are software applications that can be executed (run) on a mobile platform (i.e. handheld commercial off-the-shelf computing platform, with or without wireless connectivity) or a web-based software app tailored to a mobile platform but executed on a server.[111] South Africa leads in the number of mobile app downloads in Africa,[112] with 62% of South African consumers owning a connected mobile device and 21% using the device to access healthcare information.[113] The recent and continued development of technology-based nutrition and dietary assessment tools has also been reported,[110,114-126] with evidence supporting that technology-based health interventions may be an effective strategy for improving health promotion behaviours.[127]

2.3.1 Technology in dietary screeners

A national survey of mobile phone owners in the United States found that 58% of mobile phone users had downloaded a health-related app. Most people used the apps at least daily, with fitness and nutrition apps the most common categories of downloads.[128] Nutrition-related apps have been associated with health-promoting behaviours,[127] with research suggesting that the use of these apps leads to behaviour change, such as increased goal setting to follow a healthy diet and increased frequency and consistency of eating healthy foods.[129] The use of technology-based methods has also shown potential benefits for health promotion in childhood obesity,[130] improved HbA1c levels in type 1 diabetes,[131] self-monitoring of weight loss,[132,133] and increased fruit and/or vegetable consumption.[135,135]

Traditional dietary screening tools pose inherent challenges and limitations relating to reliability, validity, sensitivity, and specificity.[136] Technology has the potential to improve and enhance the accuracy and efficiency of such tools.[39,136-139] Compared with traditional versions, a greater preference, satisfaction and acceptability have been reported with the use of technology-based versions of dietary screeners.[115,116,139-149]

2.3.2 Strengths and limitations of technology-based dietary screeners

Dietary screeners could leverage technology for entry into the nutrition care process,[150] while addressing some limitations of traditional dietary screening tools. Research suggests that the underlying methodology of dietary screening is unchanged by technology[116,137,145] and offers the potential of improved efficiency.[136,139] The general strengths of technology-based dietary screeners include:[27,28,42,136,137,147,151]

- User-friendly, flexible, and easily accessible.
- Potential for reducing respondent burden and increasing respondent co-operation, compliance, and acceptance.
- Increased co-operation and compliance of self-monitoring.
- More acceptable and greater appeal and relevance to younger populations.

- Real-time data collection facilitates better data quality with higher degree of validity and reliability related to improve data quality, completeness, and consistency, reduced memory bias, and internal checks to flag missing, incomplete or implausible answers.
- Reduce cost of data collection and less laborious data collection.
- Collection of long-term data more feasible due to lower respondent burden.

However, technology-based versions are not free of limitations. High development and set-up costs, the need for secure internet access, and limited use in populations who are not familiar with technology (e.g. elderly) pose limitations.[28,42] Participant training on how to use the technology may thus be required. It is important to remember that the same measurement errors related to the methodology of these screeners remain, regardless of whether using a traditional or technology-based version, such as inherent bias related to self-reporting.[27,28,147] There is also a gap between consumer and academic applications of new dietary assessment and screening methods.[151]

Technology-based versions of food records exist.[122,152,153] Advantages include the reduced burden of data entry, decreased workload and costs, and potential decreased transcription errors.[148] Technology-based food records have been found to be as accurate as paper-based versions but more acceptable by the user.[116] However, technology-based foods records are generally more popular among consumers than researchers as the manual entry of food items into the food record challenges the scientific soundness of the tool.[154]

In South Africa, researchers assessed mobile health apps as dietary self-monitoring tools.[154] MyFitnessPal, a food record in a mobile app format, was reported to be easy to use (93.4%) though participants reported challenges in the selection of food items (39.3%) and portion sizes (63.9%). Participants reported that MyFitnessPal helped to change their dietary intake (91.8%) and reach weight and health goals (65.6%). A significant reduction ($P = 0.03$) in the intake of high-sugar food after the use of MyFitnessPal for over three weeks was found, with the use of the app leading to a significant reduction in sugary food intake.[154]

Technology-based 24-hour dietary recalls have also been developed[114,115,117,118,121,123,124,126,155-157] and the performance compared with traditional

(paper-based) versions, which was reported to be well-received by users.[26,114,115,119,121,158] The adaptation of interviewer-led 24-hour dietary recalls to self-administered/online versions have the potential to enhance the feasibility and cost-effectiveness of high-quality data collection as handwriting illegibility is minimised.[26] The same trend of FFQ in technology-based formats has also been seen.[75,119,142,144,159-162]

2.3.3 The development of technology-based dietary screeners

Recommendations to guide the development, evaluation and validation of traditional (paper-based) FFQs have been published (Annexure B).[163] Given the growing popularity, the evaluation of technology-based dietary screening tools may help to understand the potential to replace, improve, or complement such methods. For this, the ILSI Europe Dietary Intake and Exposure Task Force developed best practice guidelines consisting of five steps to report on technology-based dietary assessment tools, as listed in Table 2.2.[164]

2.4 The Evaluation of Technology-based Dietary Screeners

Mobile- and web-based dietary screeners are evaluated and assessed in terms of usability, which is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.[165] The usability of dietary screening and dietary assessment tools has been studied by various researchers.[125,157,160,166-170]

2.4.1 Tools to evaluate web- and mobile-based applications

To date, there has been no consensus on the best practice method for evaluating the usability of health-based mobile apps.[171,172] In addition, many tools fail to provide interpretation guidelines of the ratings such that researchers are unable to correlate scores to define a usable/acceptable app.[173] While tools have been proposed to evaluate the quality of general apps,[174,175] evaluation tools more specific to the evaluation of health-related apps include the Mobile Application Rating Scale (MARS),[176] uMars,[177] the App Quality Evaluation (AQEL) tool,[178] and Transparency, Health Content, Excellent Technical Content, Security/Privacy, Issues of Usability and Subjective Ratings (THESIS).[179]

Table 2.2: Best practice guidelines for reporting new technologies for dietary assessment (adapted from Elridge et al.)[164]

Step	Comment
Step 1 – What is the specific purpose of the tool?	▪ Define the use, e.g. research, surveillance, or direct consumer use. ▪ Determine the population characteristics, e.g. age, sex, health status, education level, literacy level, cultural diversity. ▪ Specify the period of interest. ▪ Stipulate the level of accuracy/precision needed.
Step 2 – Indicate the measures of the tool	▪ Report on food, food groups, nutrients, food components. ▪ Specify dietary behaviours and primary items of interest. ▪ Provide an indication of absolute or relative intake estimates. ▪ Provide an indication if estimates are on an individual or group level. ▪ Indicate whether information on habitual total dietary intakes or temporal intakes is collected. ▪ Provide supplementary information, e.g. physical activity, health characteristics, and dietary supplements.
Step 3 – What is the platform/technology of the tool?	▪ Specify the platform, e.g. tablet, computer or mobile app. ▪ Indicate available resources and limitations, e.g. funding, logistical conditions, logistical constraints, staff, and food composition database used.
Step 4 – Are there customisation features of the tool?	▪ Determine the type of data entry (manual or assisted), e.g. image capturing and scanning of barcodes. ▪ Determine the required precision for identifying foods and/or portions. ▪ Clarify the portion size estimation method, e.g. household measures or standard measures. ▪ Determine the customisation features, e.g. missing items or customisation of recipes. ▪ Determine whether data can be exported to other devices. ▪ Indicate whether feedback or self-monitoring provided. ▪ Determine the type of dietary information, e.g. total energy, macronutrients, micronutrients, food groups, meal occasion, or time of intake.
Step 5 – Report on the design, pretest, and validation of the tool	▪ Assess user-friendliness/ease of use. ▪ Assess user feedback/acceptability. ▪ Determine time to completion of assessment. ▪ Validate tool, e.g. reference standard.

Of these evaluation tools, MARS is the most used for assessing the quality and functioning of mobile health apps,[107] and the continued validation of this tool has been called for.[180] MARS is a simple, objective tool to critically appraise the quality of mobile apps and is a reliable measure for trialling, classifying, and rating the quality of mobile health apps. MARS is a highly reliable tool that has demonstrated excellent internal consistency ($\alpha = 0.9$) and interrater reliability [intraclass correlation coefficient (ICC) = 0.79)].[176] It has been used to evaluate a range of mobile apps such as general healthy lifestyle apps,[107] Covid-19,[181] weight loss/ management,[182,183] mindful eating,[184] and heart failure.[185] Italian,[186] Spanish,[187] and German[188] versions have been adapted and validated.

Further to this, uMARS was developed, validated, and adapted for lay users by simplifying items and removing those that require professional or content expertise as shown in Table 2.3.[177] uMARS has excellent internal consistency ($\alpha = 0.90$) with a high α for all subscales (engagement $\alpha = 0.80$; functionality $\alpha = 0.70$; aesthetics $\alpha = 0.71$; information $\alpha = 0.78$; satisfaction $\alpha = 0.78$). Both the total uMARS score and individual subscales have good test-retest reliability.[177] uMARS has been used in evaluation studies of mobile apps used by healthcare professionals such as occupational therapists.[189]

Further to MARS and uMARS, THESIS is 27-item rating tool with fair interrater reliability ($k = 0.3–0.6$) and excellent scale reliability ($\alpha = 0.85$).[179] Likewise, AQEL is a 51-item instrument for evaluating the educational quality and technical functionality of mobile apps. AQEL has good test-retest reliability with no significant change over time ($P > 0.05$) and good internal consistency ($\alpha = 0.8$). AQEL is a valid, reliable instrument for evaluating the qualities of nutrition-related apps for clinical interventions by nutrition clinicians, educators, and researchers.[178]

Table 2.3: The uMARS subscale and items: mean scores and total score calculation (adapted from Stoyanov et al) [177]

Score	Subscale	Item	Mean score	Total score
App quality rating (objective)	A. Engagement	1. Entertainment 2. Interest 3. Customisation 4. Interactivity 5. Target group	Engagement mean score	**App quality mean score = (A + B + C + D)/4**
	B. Functionality	6. Performance 7. Ease of use 8. Navigation 9. Gestural design	Functionality mean score	
	C. Aesthetics	10. Layout 11. Graphics 12. Visual appeal	Aesthetics mean score	
	D. Information	13. Quality of information 14. Quantity of information 15. Visual information 16. Credibility of source	Information mean score	
App subjective quality (subjective)	E. Subjective quality	17. Would you recommend this app? 18. How many times do you think you would use his app? 19. Would you pay for this app? 20. What is your overall star rating of the app?	Subjective quality mean score	**App subjective quality score**
App-specific	F. App-specific	21. Awareness 22. Knowledge 23. Attitudes 24. Intention to change 25. Help seeking 26. Behaviour change	App-specific mean score	**App-specific score**

However, when comparing AQEL with uMARS, AQEL has been validated for nutrition-related apps for use by nutrition educators, clinicians, and researchers. In contrast, uMARS does not require users with professional or content expertise.[178] Validation studies have shown good internal consistency (α = 0.8) of AQEL and excellent internal consistency (α = 0.90) compared with the high α for all the subscales for uMARS (engagement α = 0.80; functionality α = 0.70; aesthetics α = 0.71; information α = 0.78; satisfaction α = 0.78). While both tools show good test-retest reliability, the smaller sample size (n = 15) in the validation of AQEL is a limitation compared with the much larger sample size (n = 164) in the validation of uMARS. Additionally, uMARS can include ratings on scientific evidence of the mobile app, and information is important in research when considering incorporating mobile apps into intervention studies.[173]

2.4.2 The role of nutrition professionals in technology-based dietary screeners

With mobile apps escalating in popularity, capability and accessibility, nutrition professionals have a vital role to play in collaborating with mobile app developers to adopt the use of health- and nutrition-related apps into practice.[171,190] App developers should draw on the features and characteristics valued by dietitians to guide in the development of apps to support dietetic practice.[191] Mobile app evaluation tools should provide input from professionals,[191] adopt a user-centred model incorporating the user's design preferences,[192] and include an assessment of usability, promotion of behaviour change and evaluation of content quality.[107]

In South Africa, recommendations of nutrition and health-related mobile app use is, to the best of the researcher's knowledge, unknown among South African healthcare professionals, including nutritional professionals such as dietitians and nutritionists. Internationally, Australian medical doctors recommend mobile apps to patients either daily (12.9%), weekly (25.9%) or monthly (13.4%).[193] The lack of knowledge regarding the effectiveness of apps (59.9%) and the lack of trustworthiness of the app (15.5%) were cited as barriers to app prescription among medical doctors.[193] In a survey on healthcare professionals (n = 1 001) from 73 countries (833 dietitians, 75 doctors, 62 nurses), 45.5% of respondents recommend apps to clients/patients. Important criteria for selecting an app were ease of use (87.1%), apps being free of charge (72.6%), and validation of apps (69.0%).[194]

More specific to nutrition professionals, app usage is greater among dietitians from Canada (40%),[195] dietitians of the Australian, New Zealand and British dietetic associations (62%)[196] and dietitians from the United States (79%).[197] In the Clinician Apps Survey (n = 583), 94% of clinicians, including registered dietitian nutritionists, certified diabetes educators, and registered nurses, recommended traditional (paper-based) dietary assessment methods and 85% also recommended the use of apps.[198] Recommendations of nutrition and health-related mobile app use is high among dietitians from the United States between 79%[197] and 83%.[199]

Lower mobile app use in dietitians has been reported in Canada (57%)[195] and in a study on sports dietitians in Australia, Canada, New Zealand, the United States and the United Kingdom (32%).[200] Furthermore, dietitians report apps as "better" (47%) or "equivalent" (41%) than traditional dietary assessment methods.[200] Research among dietitians shows that apps are superior to traditional dietary assessment methods in monitoring dietary intake (88%), tracking physical activity (83%), making better food choices (72%), tracking weight loss (64%), and managing blood glucose control (52%).[198] Despite this, when evaluating 16 nutrition-related apps in Brazil, mobile apps were not found to be useful for nutritional guidance as most are not based on reliable sources of information.[201]

2.5 The Development and Validation of Dietary Screeners

The development of dietary screeners, both in traditional[163] and technology-based[164] formats have been reported. Recommendations for the development, evaluation and validation of an FFA as a dietary screener are shown in Table 2.4.

2.5.1 Development of dietary screeners

In the development of a dietary screening tool, no uniform best practice exists.[202] A common analytical approach is to allocate a score to each category or question of the variables in the dietary screener. Thereafter, the summed final score represents the risk of malnutrition or the nutrition-related risk in question.[202] Based on the final score, patients may be referred for a full nutrition assessment.

Table 2.4: Summary of recommendations for the development, evaluation and validation of an FFQ (as adapted from Cade et al., 2002[163] and Cade et al., 2004[203]) with contextualisation for this study

Recommendation	Comment	Contextualisation (relevance) for this study
FFQ design	▪ Is information needed about foods, nutrients, dietary supplements or other food constituents, or specific dietary behaviours? ▪ Is frequency of consumption required? ▪ Is amount of consumption required (i.e. portion)? ▪ Is information on one food/nutrient or a range required? ▪ Is the population mean or individual intake required? ▪ Is absolute or relative intake needed? ▪ Is information on dietary change required? ▪ What level of accuracy is required? ▪ What is the time period of interest? ▪ What are the research constraints in terms of money, time, staff and respondent characteristics? ▪ Consult a statistician and nutritionist before embarking.	The Dairy Diary has the format of a quantitative FFQ. It is intended to screen for low dairy intake in South African adults. The Dairy Diary includes information of frequency of consumption and portion sizes on food group level (i.e. of selected dairy products: milk, maas, yoghurt, cheese) consumed over a reference period of one month.
Modifying existing FFQs	▪ Modification of pre-existing FFQs for use in similar populations is useful. However, the purpose of the original and new version should be considered carefully. Adapted FFQs may not compare as well in terms of validity.	The Dairy Diary was developed as a new screener for dairy intake. Thus, no modification of pre-existing FFQs occurred.
Developing of a food list	▪ Unless the FFQ is specific and comprehensive, a long-winded food list is unnecessary and impractical.	The Dairy Diary is used to screen for low dairy intake. The food list includes milk, maas, yoghurt, and cheese.

Recommendation	Comment	Contextualisation (relevance) for this study
Grouping of food item	▪ Grouping of food items should be decided *a priori* according to the purpose of the questionnaire. ▪ Single items are preferable over grouped questions for food groups of main interest. ▪ Some grouping of foods may need to be considered to prevent excessive questionnaire length. ▪ Consider foods consumed both alone and as part of mixed dishes.	The foods in the dairy food-based dietary guideline (milk, maas and yoghurt) plus cheese were included in the Dairy Diary.
Number of days of recording	▪ Most studies rely on 2–5 days of dietary intake per participant.	In the validation study, two administrations of the Dairy Diary were completed, 14 days apart.
Sequence of administration	▪ The index test should be administrated prior to the reference standard.	Administering the index test (i.e. the Dairy Diary) first, as proposed, may sensitise the participants to their personal dairy intake. For this reason, the researcher administered the reference standard (i.e. three-day weighed food records) first, followed by the index test (i.e. the Dairy Diary).
Questions	▪ Simple and unambiguous questions are placed at the start of the questionnaire, and food groups of interest to the study soon after. ▪ If it is necessary to use open questions, the questionnaire should be interviewer-administered rather than self-administered.	The Dairy Diary is self-administered, and questions are close-ended. Clear instructions are provided. Foods are listed first (e.g. milk) followed by questions on food type (e.g. reduced fat milk) and portion size.

Recommendation	Comment	Contextualisation (relevance) for this study
Estimation of portion sizes	▪ Allowing subjects to estimate their portion size is more advantageous than using average portion sizes. ▪ Suitable methods are the use of defined small, medium and large options, and estimation of portion size using photographs.	The use of defined small, medium and large portions is used in the Dairy Diary, as guided by portion sizes for dairy in South Africa.
Method of questionnaire administration	▪ If practical, interviewer-administered FFQ should be used instead of self-administered questionnaires. ▪ If self-administered versions are used, questionnaires should be checked for completeness.	The automation of the Dairy Diary as a web-based application includes built-in checkpoints before progression.
Reference standard	▪ The reference standard must assess the diet over the same period as the test method. ▪ It is recommended that weighed food records are used as the method of choice for validation studies. ▪ Multiple days of collection of dietary data should be undertaken.	Three days of weighed food records were the reference standard in this study. It was assumed that this represented usual dietary intake.
Use of biomarkers	▪ Consider carefully what is being measured. ▪ Consider all possible errors associated with the method. ▪ Take the relevant time frame and relationship between biological variation and variation in dietary intake into consideration.	Biomarkers were not used in this study.
Sample size for validation studies	▪ Statistical advice should be sought to estimate participant numbers. ▪ If resources are available, higher numbers of subjects provide better estimates of validity. ▪ A sample size of 50–100 subjects for each demographic group is recommended.	The validation study included a final sample of 79 participants.

Recommendation	Comment	Contextualisation (relevance) for this study
Pretesting of FFQ	▪ Every questionnaire should be rigorously pretested to ensure that the meanings of the food names and the portion size descriptors are clear, instructions are clear, and that the method for recording responses is unambiguous.	The draft was reviewed and revised by a working group of dietitians and nutritionists knowledgeable in dietary assessment and dairy nutrition. Ongoing refinement took place. Software developers translated the content into a web-based application. A pilot study was conducted.
Time frame of reference standard	▪ Adequate time between test and reference standard administration is crucial in a validation study. This will enable statistical measurements of test-retest reliability. ▪ Correlation coefficients are higher for repeat administrations one month apart or less, compared with repeat administrations six to 12 months apart. ▪ Adequate time between re-administrating questionnaires will help avoid respondents remembering previous answers. Very long interval periods are not ideal as changes and variation in dietary habits could reduce the reliability of the screener.	Time frames of 2–3 weeks have been reported in similar validation studies.[101,106] To determine test-retest reliability of the Dairy Diary, two administrations of the screener were completed, two weeks apart.
Correlation, regression and the Bland–Altman method in validation studies	▪ The methods developed by Bland and Altman should be used to measure the agreement between FFQ and other measures of dietary intake. ▪ These methods should be used in context and interpreted in the light of the target population and what the acceptable levels of bias and limits of agreement are in this context.	In the validation study, correlation, Bland–Altman plots, Kappa, and sensitivity and specificity were used for statistical analysis.

Recommendation	Comment	Contextualisation (relevance) for this study
	▪ Regression or correlation may be used in conjunction with the Bland–Altman method. ▪ If correlation is used, Pearson's correlation should be used for normally distributed data, Spearman's correlation for non-normally distributed data. ▪ Kappa and/or sensitivity, specificity, etc. may be appropriate if the data is ordered, categorical or binary.	
Validation of FFQs	▪ FFQs should always be validated. ▪ Validation studies should use similar populations to the intended main study. ▪ The methods of validation must consider the purpose of the FFQ. For example, all foods and nutrients to be assessed in the main study should be assessed. ▪ Using more than one approach to validation gives added credence to the results.	This study validated the Dairy Diary in a population similar to the intended development of the dairy screening tool, that is, South African adults aged 18 – 65 years.

However, such an approach has been criticised as it prejudges the effect of the variable which may confer a bias, challenging the adequacy of the screener.[41,202] Therefore, the application of multivariate statistical methods is suggested such that the relevance and impact of independent variables related to the risk of the outcome variable are considered, validating the dietary screener.[202] This approach weighs each variable's effect on the risk of malnutrition to filter the risk factors for those that best predict malnutrition.[202]

2.5.2 Validation of dietary screeners

Validation studies play a key role in assessing the degree to which a dietary screener measures the food(s) and/or nutrient(s) for which it has been designed.[26,163,203] In validation studies, the tool's performance is assessed in terms of reliability and validity.[202,204] A dietary screener with high validity can provide useful measurements for a given purpose and context; is well-grounded in theory; its performance is consistent with that of theory; and is precise,

dependable, and accurate within specified performance standards.[205] A checklist is available to guide researchers in the contribution to strengthening the literature on the validation of dietary screening tools (Annexure B).

In the context of dietary screening, validation is the process of determining whether a measure or indicator is suitable for providing a useful analytical measurement for a given purpose and context.[205] A valid and reliable dietary screener increases the probability that a patient referred for a full assessment has a malnutrition or nutrition-related diagnosis. Furthermore, a valid and reliable screening tool avoids the unnecessary referral of patients who do not require a full assessment.[202] A reference standard, also known as a gold standard, is used in the validation of dietary screening tools. Examples of reference standards include dietary assessment methods (such as food records), biochemical tests, autopsy, biopsy, or even another screening tool.[22] However, for enhanced reliability and comparative validity, it is recommended that the measurement errors of the dietary screener and reference standard should ideally be independent,[204] i.e. an FFQ should not be used to validate another FFQ.

Newly developed dietary screening tools are evaluated for effectiveness before being established for use and are assessed in terms of reliability and validity.

2.5.3 Reliability

Reliability (or reproducibility) is the ability of a method to produce the same estimate on two or more occasions,[202,204] assuming no changes have occurred between the two administrations. Reliability is only concerned with whether a method yields the same or similar result two or more times and does not necessarily indicate whether the answer is correct. Since a method cannot give a correct answer every time unless it gives approximately the same answer each time, reliability is partly involved in addressing validity too.[202,204]

Though there are many forms of reliability, this review is limited to test-retest reliability and interrater reliability. Test-retest reliability refers to the extent to which repeated measurements of the same concept are similar.[204] Factors affecting test-retest reliability include measurement costs, feasibility of replicating the reference measure period, and the possibility of a repeat measure influencing the first measure. Ideally, the test and retest measure should be independent, and the results of the retest should not influence the results of the first test.[204]

Interrater reliability is used to assess whether different interviewers (or raters) use the measure and achieve comparable results from the same subjects. Intrarater reliability assesses whether the same answers are obtained.[163] Given that these types of reliability are interviewer-dependent, this measure of validation is not required in self-administered FFQs.

2.5.4 Validity

Validity is the ability of an instrument to measure what it is intended to measure.[202,204] To validate a dietary screener, the researcher compares estimates of food and/or nutrient intake from the screener to estimates from a reference standard, such as food records.

Since it is challenging to evaluate true usual intake, researchers use absolute validity (the extent to which a measure exactly captures the concept it is intended to reflect), the highest standard of validity.[204] Absolute (or criterion) validity is the highest form of validity, assessing the extent to which a measure accurately reflects the exact concept it is intended to reflect.[204]

Face validity (the extent to which a measure appears to most observers to capture the concept it is intended to capture) and content validity (the extent to which measure overs all dimensions present in the concept it is intent to reflect) are subjective measures with no statistical tools.[204]

Lastly, comparative validity, also known as relative validity, is assessed by comparing an index test with a reference standard where the reference standard has a greater degree of demonstrated validity, even if not an exact measure.[204] Both the index test and reference standard must measure the same underlying concept over the same time period. Since both an index text and reference standard are inherently limited by some degree of inaccuracy, the methods should be independent to avoid correlation of errors.[204] For example, the FFQ relies on memory and can be validated against weighed food records where participant memory is not needed.[204]

2.5.5 Sensitivity and specificity

Given that a dietary screener aims to identify risk and thus the need for further comprehensive dietary assessment, it is important to not overlook those who may have the disease. In other words, false negatives should ideally be avoided, and false positives are more likely to be accepted. For this, the validation of dietary screening tools may use statistical tests, such as sensitivity and specificity. Sensitivity is the proportion of those with the target condition who test positive with the index test.[204] Specificity is the proportion of those without the target condition who test negative with the index test.[204] Table 1.2 summaries the definitions and equations related to sensitivity and specificity.

In theory, dietary screening tools should have high sensitivity and specificity for good accuracy to detect the nutrition risk while identifying nutrition-related outcomes.[22,23,35] As such, all subjects screened are correctly identified as at risk (sensitivity) or not at risk (specificity). A screening tool with high sensitivity is more likely to correctly identify patients who have nutrition problems, with a low percentage of false negative results.[35] A test that is highly sensitive is assumed to correctly rule out nutrition problems in those with negative screening results. In contrast, a screening tool with high specificity results means greater level of identification of patients who do not have a nutrition problem and a lower level of false

positive tests.[35] A test with a high sensitivity but low specificity results in many patients who are disease-free being told of the possibility that they have the disease. If the clinician is more interested in accurate identification of patients who might have nutrition problems, then a test with a high level of specificity should be selected.[35] In most situations, this may be unrealistic and thus a balance must be considered.

2.5.6 Predictive values

Predictive values are also related to sensitivity and specificity, and these statistical tests are particularly important when nutrition screening is conducted by non-nutrition professionals who may alert the dietitian to the at-risk patient.[22]

PPVs are a measure of the probability of having the disease/condition if the result of a diagnostic test for the presence of a particular condition or disease is positive (i.e. indicates the condition or disease is present). A higher PPV indicates that the test is effective at establishing the condition or disease.[204]

Negative predictive value (NPV) measures the probability of a given case not having a condition or disease if the result of a diagnostic test for the presence of a particular condition or disease is negative (i.e. indicates the condition or disease is not present). Higher values of the negative predictor value indicate that the test is effective at ruling out the condition or disease.[204]

A low NPV value may require that the subject be rescreened by the dietary screening tool as this may indicate that the tool may overlook patients at risk.[22] A high PPV and high NPV screening correctly identifies patients in need of a complete dietary assessment (i.e. those who screen positive are likely to be malnourished and those who screen negative are unlikely to be malnourished).[22]

2.5.7 Statistical tests for validation of dietary screeners

There is no consensus on the most suitable statistical test(s) for validating dietary screeners.[204,206,207] Up to three statistical tests may not be adequate and multiple tests

representing various aspects of validity are superior with a combination of several statistical tests recommended.[208]

Similar statistical techniques to assess reliability can be used to assess validity.[204] First, correlation coefficients (e.g. Intraclass, Spearman and Pearson) measure the strength and direction of a relation between two variables and not the agreement.[209,210] The correlation coefficient is the most used statistical test when validating dietary intake assessment methods[206,208] and have been used in previous validation studies on web- and mobile-based FFQs.[75,162]

The Pearson correlation coefficient (*r*) is used for continuous data that are distributed normally.[204,207,210] When data are ordinal and not normally distributed, Spearman correlation (rho) is used.[204,207,210] Given that ordinal data can also be ranked, the Spearman correlation coefficient is not restricted to continuous variables.[210] Confidence intervals further provide a range of plausible values of the estimate of a correlation coefficient.[210]

The correlation coefficient is calculated as the ratio of covariance between two variables to the product of the standard deviation (SD). Values range from −1.0 to +1.0, indicating the strength of relationship between the variables. The closer the coefficients are to −1.0 or +1.0, the stronger the relationship.[211] Furthermore, correlation coefficients are translated into descriptors such as weak, moderate, or strong. Correlation strength can be poor ($r < 0.2$), moderate ($r = 0.2–0.6$) or strong ($r > 0.6$).[212,213] Nonetheless, Schober et al.[210] caution that such cut-off values are arbitrary and inconsistent. In a meta-analysis of the reliability of FFQs in nutritional epidemiological studies, Cui et al.[214] propose that FFQs with correlation coefficients greater than 0.5 may be considered a valid tool for measuring dietary intake.

However, a high correlation does not imply good agreement between two methods.[211] Given that correlation coefficients only examine the relationship between two variables and not the difference, using this statistical analysis exclusively can be misleading.[209,211] Thus, an alternative statistical analysis was proposed, namely the Bland–Altman method,[209] which uses graphical techniques and calculations and quantifies the agreement between two measures by assessing the mean difference and constructing limits of agreement (LOA).[209] The 95% LOA estimates the mean difference (±1.96 SD) and provides an agreement interval within which

95% of the differences of the second method are expected to lie compared with the first method,[211] reflecting both over- and underestimation. The resulting scatter plot illustrates the magnitude of disagreement and identifies outliers and bias, with data as the difference between the measurements (i.e. test measure – reference measure; y-axis) against the mean of the two measures (i.e. test measure + reference measure/2; x-axis).[209] This indicates the presence, direction, and extent of bias at a group level ($P > 0.05$ = good; $P \leq 0.05$ = poor).[209]

This method is superior to other measures of agreement as it can analyse whether the extent of the agreement differs for low versus high intakes and can best determine systematic differences between repeat administrations (bias) and to what extent the two administrations differ (i.e. LOA).[163,209] However, the Bland–Altman method does not indicate whether the agreement is suitable: rather it quantifies the bias and the range of agreement within which 95% of the differences lie. Thus, researchers are required to *a priori* establish the clinically relevant and acceptable LOAs[215] and, thereafter, use statistical analysis to indicate whether the limits are exceeded.[211] If reliability is relevant to the study, the repeatability of the two methods of measurement limits the amount of agreement that is possible.[209] Thus, the Bland–Altman method is often used in validation studies (where reliability is a prerequisite).

Another statistical test, the Kappa statistic (κ), assesses interrater agreement for categorical data.[206] This statistic does not consider the degree of disagreement between methods and all disagreement is treated equally. Furthermore, it does not indicate whether agreement (or lack thereof) is due to systematic differences between the two methods or due to random differences. Strength of agreement for Kappa can be described as poor ($\kappa < 0$), slight ($\kappa = 0.01$–0.2), fair ($\kappa = 0.21$–0.40), moderate ($\kappa = 0.41$–0.60), strong ($\kappa = 0.61$–0.80), and almost perfect ($\kappa = 0.81$–1.0).[216]

More specific to diagnostic accuracy studies, the Standards for Reporting Diagnostic Accuracy Studies (STARD) statement as shown in Table 2.5 was developed to contribute to the quality of reporting of diagnostic accuracy studies.[217] Diagnostic accuracy is the amount of agreement between information from an index test and the reference standard.[217] Diagnostic accuracy studies are at risk of bias related to methodological differences.[217] Sensitivity and specificity are related to reliability and validity[204] and are an approach to quantifying the diagnostic

ability of the test.[217] Diagnostic accuracy studies are also quantified by other statistical measures such as predictive values, likelihood ratios, among others.

Table 2.5: STARD 2015 guidelines for reporting diagnostic accuracy studies (adapted from Cohen et al)[217]

Section	Item
Title or abstract	
▪ Does the title or abstract identify as a study of diagnostic accuracy using at least one measure of accuracy (e.g. sensitivity, specificity, predictive values)?	
Abstract	
▪ Is there a structured summary of study design, methods, results, and conclusions?	
Introduction	
▪ Is there a scientific and clinical background, including the intended use and clinical role of the index test? ▪ Are study objectives and hypotheses mentioned?	
Methods	
Study design	▪ Was data collection planned before or after the index test and were reference standards performed?
Participants	▪ Were eligibility criteria indicated? ▪ On what basis were potentially eligible participants identified? Where and when were potentially eligible participants identified? i.e. date, location, setting. ▪ Did participants form a consecutive, random or convenience series?
Test methods	▪ Is the index test described in sufficient detail to allow replication? ▪ Is the reference standard described in sufficient detail to allow replication? ▪ What is the rationale for choosing the reference standard? ▪ Provide a definition of and rationale for test positivity cut-offs or result categories of the index test, distinguishing prespecified from exploratory. ▪ Provide a definition of and rationale for test positivity cut-offs or result categories of the reference standard, distinguishing prespecified from exploratory. ▪ Were clinical information and reference standard results available to the performers/readers of the index test? ▪ Were clinical information and index test results available to the assessors of the reference standard?

Section	Item
Analysis	▪ What were the methods for estimating measures of diagnostic accuracy? ▪ How were indeterminate index test or reference standard results handled? ▪ How were missing data on the index test and reference standard handled? ▪ Are there any analyses of variability in diagnostic accuracy, distinguishing prespecified from exploratory? ▪ What was the intended sample size and how it was determined?
Results	
Participants	▪ Was the flow of participants presented using a diagram? ▪ Was the baseline demographic and clinical characteristics of participants described? ▪ What was the distribution of severity of disease in those with the target condition? ▪ What was the distribution of alternative diagnoses in those without the target condition?
Test results	▪ Cross-tabulate the index test results (or their distribution) by the results of the reference standard. ▪ Estimate the diagnostic accuracy and the precision thereof (such as 95% confidence intervals). ▪ Are there any adverse events from performing the index test or the reference standard?
Discussion	
▪ Were study limitations indicated (e.g. sources of potential bias, statistical uncertainty, and generalisability)? ▪ What are the implications for practice, including the intended use and clinical role of the index test?	
Other information	
▪ Provide the registration number and name of registry. ▪ Indicate where the full study protocol can be accessed. ▪ Declare sources of funding and other support, including role of funders.	

2.5.8 The validation of FFQs as dietary screeners for dairy intake

A review of available literature identified 17 studies on dietary screeners for adults, which included calcium or dairy products as a food item (Table 2.6). The date of the studies ranged from 1995[89] to 2021.[99] A large range of sample sizes were noted, from 27[90] to 751.[103] A sample of at least 50, preferably 100, is recommended to validate FFQs.[203]

The number of items in the dietary screeners ranged from six[99,105] to 166.[103] Of these screeners, 11 (65%) were food-based and seven (41%) calcium- and/or dairy-based. Only one screener was dairy-based alone.[218] . Most (71%) dietary screeners were developed for use in North American and European populations, followed by Australian (24%) populations. Few were based on Asian populations (12%). No dairy intake screeners were identified in South Africa. Thirteen (76%) of the studies used paper-based screeners and four (24%) used technology-based (online or app-based) versions (see Table 2.6).

Of the 17 studies (see Table 2.6), most (94%) reported on the validation of the dietary screener, with one (6%) study reporting on the reliability only.[98] In the studies that validated the dietary screeners, almost half (47%) used three- to seven-day weighed food records as the reference standard. Weighed food records have the fewest correlated errors with FFQs as the errors are largely independent, and if anything, validity is understated.[163] For enhanced reliability and comparative validity, the measurement errors of the index test (i.e. dietary screener) and reference standard (i.e. food records) should be independent. A seven-day weighed food record is considered appropriate but respondent burden is high and compliancy low. Thus, shorter periods of 2–5 days are generally accepted.[163]

Systematic errors were evident in the studies. A limitation in the study by Hacker-Thompson et al.[95] involved the participant completion of three-day weigh food records after the participants were exposed to the index test, which may introduce a systematic error of recall bias.[204] Furthermore, two studies (12.5%)[23,105] used 24-hour dietary recalls and two studies (12.5%)[97,99] used another FFQ for validation. Again, this approach would introduce a systematic error to the study as the reference standard and the index tool, both FFQs, would share similar error structures. Rather, the two methods should be independent of each other to avoid such errors.[204]

A range of various combinations of statistical tests were reported. Fourteen (82%) studies reported on correlation coefficients, nine (53%) reported Bland–Altman plots with LOA, and seven(41%) reported on Kappa statistics for statistical analysis. Only two (12%) reported on ICC (see Table 2.6). Sensitivity and specificity are an approach for quantifying the diagnostic ability of the test as recommended by the STARD 2015 guidelines.[217] Yet, sensitivity and specificity were only reported in five (29%) studies, ranging from sensitivity values of 55.6%[99] to 97%,[98] and specificity values from 12.0%[98] to 86.6%.[91] Diagnostic accuracy studies are also quantified by predictive values, likelihood ratios, and ROCs,[217] but only one (6%) study reported on ROC and one (6%) study reported PPVs.

Table 2.6 summarises the calcium- and dairy-based dietary screeners in adults.

Table 2.6: Summary of calcium- and dairy-based dietary screeners in adults

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
1.	Welten et al. (1995);[89] Netherlands; Dairy Questionnaire/qFFQ; Paper-based.	Diet history; N = 166; n = 29 in reliability study (27–29 years).	61-item; Calcium-based from dairy products only (dairy products [e.g. cheese, milk and milk products] and mixed dishes based on dairy products (e.g. pancakes and sauces).	✓ Correlation coefficients: Pearson. ✓ Kappa statistics. × Sensitivity. × Specificity. × Bland–Altman plots with LOA.	▪ Moderate reliability and validity. ▪ Pearson and Kappa correlation coefficients reported for cheese and milk (r=0.58; κ=0.67 vs. r=0.65, κ=0.60, respectively) ▪ Good agreement (r=0.78, P-value not reported) ▪ Recall bias ▪ Small sample size of the reliability study
2.	Hodge et al (2000);[104] Australia Anti-Cancer Council of Victoria FFQ/FFQ; Online.	Seven-day weighed food records; N = 63 (16–48 years; female; 33.3 ± 9.5 years).	74-item; Food-based: dairy products (e.g. cheese, yoghurt, milk in cereal, milk in porridge, milk in all other forms).	✓ Correlation coefficients: Pearson, Spearman. ✓ Bland–Altman plots with LOA. × Sensitivity. × Specificity.	▪ Generalisability limited to female population.
3.	Montomoli et al. (2002);[91] Italy. Unnamed/qFFQ; Paper-based.	14-day estimated food records; N = 206 (25–75 years).	15-item; Calcium-based: dairy products (milk, yoghurt, cheese, butter cow milk curd, butter sheep milk curd), pasta, rice, bread,	✓ Correlation coefficients: Pearson. ✓ Sensitivity. ✓ Specificity. ✓ PPVs.	▪ Large sample size. ▪ Dietitian administered. ▪ High sensitivity (82.8%) and specificity (86.6%).

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
			potatoes, fish, meat, eggs, legumes, vegetables, fruit, ice cream, milk chocolate, calcium-rich water.	✓ Bland–Altman plots with LOA.	▪ Not assessed for reliability. ▪ Sampling bias.
4.	Blalock et al. (2003);[90] The United States; Short screening instrument based on the Block National Cancer Institute Health Habits and History Questionnaire/FFQ; Paper-based.	Seven-day weighed food record; N = 27.	22-item; Calcium-based: foods high in calcium and vitamin D (e.g. mixed dishes with cheese), dairy (e.g. cheese and cheese spreads but excluding cottage cheese, yoghurt, milk), frozen yoghurt, ice cream, oysters, shrimp, salmon, tuna, liver, eggs, high fibre cereals, biscuits, muffins, dark bread, white bread.	✓ Correlation coefficients: not specified. ✓ PPVs. × Sensitivity. × Specificity. × Bland–Altman plots with LOA.	▪ Small sample size.
5.	Gans et al. (2006);[106] USA; Rapid Eating and Activity Assessment for Patients; Online.	Three-day weighed food records; N = 94 (43.2 ± 12.5 years).	32-item; Food-based: foods high in calcium (e.g. dairy), fruit, vegetables, red meat, alcohol.	✓ Correlation coefficients: Pearson and Spearman × Sensitivity. × Specificity. × Bland–Altman plots with LOA.	▪ Excellent test-retest reliability (r = 0.21; P = 0.04). ▪ Convenience sample for validation and reliability testing in consumer's limits generalisability. ▪ Self-administered.
6.	Clover et al. (2007);[93] Australia;	Four-day weighed food records;	35-item; Calcium-based: milk-based beverages (7), dairy products	✓ Bland–Altman with LOA. ✓ Sensitivity.	▪ Validated in an older population.

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
	qFFQ; Paper-based.	N = 102 (≥ 65 years).	including cheese, yoghurt and dairy-based dessert (13), bread and breakfast cereals (8), volume of milk added to beverages, breakfast cereals and porridges (5), type of milk used (1), type of bread used (1).	✓ Specificity.	▪ Volunteer participants more likely to be healthier.
7.	Sebring et al. (2007);[94] The United States; Dietary history questionnaire (DHQ), calcium questionnaire, and short calcium questionnaire qFFQ; Paper-based.	Seven-day weighed food records; N = 341 (38 ± 11).	124-item (DHQ), 87-item (calcium questionnaire) and 25-item (short calcium questionnaire); Calcium-based.	✓ Correlation coefficients: Spearman, Kendall rank. ✓ Bland–Altman plots with LOA.	▪ Large sample size. ▪ Participants aware of study addressing calcium intake, which may create bias and improved recording of calcium-containing foods.
8.	Hacker-Thompson et al. (2009);[95] The United States; Unnamed/qFFQ; Paper-based and online.	Three-day weighed food records; N = 140 (49 ± 15 years).	34-item; Calcium-based: 34 calcium-containing foods.	✓ Correlation coefficients: Pearson. ✓ Bland–Altman plots with LOA.	▪ Food records (reference standard) completed after FFQ administration (index test). ▪ Not assessed for reliability. ▪ No LOAs reported. ▪ Generalisability limited as only females included in population.

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
9.	Miller et al. (2010);[98] Australia; FFQ_{CA}/FFQ; Paper-based.	Only reliability reported; therefore, no reference standard for validation; N = 100 (77 ± 6.0).	35-item; Calcium-based: milk-based beverages (7), dairy products including cheese, yoghurt and dairy-based dessert (13), bread and breakfast cereals (8), volume of milk added to beverages, breakfast cereals and porridges (5), type of milk used (1), type of bread used (1).	✓ ICC to report on reliability. ✓ Validated by Clover et al. (2007)[93]	▪ Moderate reliability reported (ICC: *r*–0.5). ▪ Generalisability limited to elderly population.
10.	Goldbohm et al (2011);[102] Netherlands; qFFQ/FFQ; Paper-based.	Three-day weighed food records; N = 109 (55–69 years).	150-item; Food-based: 9 items on milk and milk products.	✓ Correlation coefficient: Spearman. × Sensitivity. × Specificity. × Bland–Altman.	▪ Spearman correlation coefficients for milk and milk products (*r* = 0.60) and cheese (*r* = 0.61). ▪ Self-administered. ▪ Possibly long time to completion (150-item). ▪ Large sample size.

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
11.	Park et al. (2013);[97] Korea; Korean Calcium Assessment Tool/qFFQ; Paper-based.	KNHANES (63-item); N = 256 (48.0 ± 13.2 years).	45-item; Calcium-based: dairy products (e.g. milk, fermented milk, cheese, yoghurt, ice cream).	✓ Correlation coefficient: Pearson. ✓ Kappa statistics. ✓ Bland–Altman plots with LOA.	▪ Selection bias. ▪ Systematic error: reference standard and index tool share similar error structures (i.e. both are FFQs). ▪ Generalisability limited to Korean females.
12.	Rasch et al. (2017);[218] Netherlands; Short Calcium Intake List (SCaIL)	Dietary history N = 66 (65.8 ± 12.1 years).	3 close-ended questions -item; dairy based(e.g. milk, buttermilk, dairy drinks, yoghurt, quark, custard, pudding, porridge, cheese) with additional question on calcium supplementation	✓ Kappa statistics ✓ Sensitivity. ✓ Specificity. ✓ Bland-Altman plots with LOA.	▪ Sensitivity: 73% ▪ Specificity: 80% ▪ Reliability not reported (only content validity) ▪ Limited number of items recorded. ▪ Dietary assessment method (i.e. dietary history) not the gold standard for validity studies. ▪ Information bias ▪ Generalisability limited to elderly population.
13.	Gilsing et al. (2018);[69] Canada;	Four 24-hour dietary recalls using the automated self-	36-item; Food-based: nutrients (total fat, fatty acids, dietary fibre,	✓ ICC. ✓ Correlation coefficient: Spearman.	▪ Good relative validity for calcium (and vitamin D and fibre).

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
	short diet questionnaire/ non-quantitative FFQ; Online.	administered 24-h questionnaire; N = 232 (62 ± 9.1).	calcium, vitamin D), fruits, vegetables.	✓ Kappa statistics.	▪ Large sample size.
14.	Martela et al. (2019);[70] Poland; Short food frequency questionnaire/semi-quantitative FFQ; Paper-based.	Three-day weighed food records; N = 156.	Not reported (12 close-ended questions). Calcium-based: dairy (milk, fermented dairy, cheese), fish, preserved meat, soy, sausages, smoked meat, wholegrains, leafy green vegetables, fruit, seeds.	✓ Correlation coefficients: Pearson, Spearman. ✓ Kappa statistics. ✓ Sensitivity. ✓ Specificity. ✓ Bland–Altman plots with LOA.	▪ High sensitivity (97%) and low specificity (12%). ▪ Large sample size. ▪ Food records (reference standard) completed after FFQ (index test).

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
15.	Gadowski et al. (2020);[105] Australia; Australian short dietary screener/qFFQ; Paper-based.	Three 24-hour dietary recalls; N = 100 (76.8 ± 4.5 years).	Six-item; Food-based: vegetables, fruits, legumes and beans, cereals, protein, dairy.	✓ Correlation coefficients: Pearson. ✓ Kappa statistics. ✓ Bland–Altman plots with LOA.	▪ Good relative validity and reproducibility. ▪ Cohen's kappa statistic for dairy: κ = 0.44. ▪ Spearman rank for dairy: *r* = 0.71. ▪ Paper-based administration relevant for older population. ▪ High completion rate (73%). ▪ Time efficient (short dietary screener). ▪ Good gender representation. ▪ Predominantly Australian-born/English-speaking and older population limits generalisability.

No.	Researchers (year); Country; Name of screener/type of screener; Format of screener	Reference standard for validation; Population size (age)	Number of items in screener; Food-, calcium- or dairy-based	Statistical tests for validation	Comments
16.	De Rijk et al. (2021);[103] The Netherlands; Eetscore FFQ/qFFQ; Online.	Dutch Healthy Diet Index 2015 (DHD2015-index); N = 751 (56.9 ± 15.8 years).	166-item (full length Eetscore) and 55-item (Short Eetscore); Food-based: vegetables, fruit, wholegrains, legumes, nuts, dairy products, fish, tea, fats and oils, coffee, red meat, processed meat, sweetened beverages, fruit juices.	✓ Correlation coefficient: Kendall's tau-b. ✓ Bland–Altman plots and LOA. ✓ ICC. × Sensitivity. × Specificity.	▪ Good (0.4 = 0.69) to excellent (≥ 0.75) reproducibility. ▪ Large sample size. ▪ Not validated against a dietary assessment/ screening method but an index score.
17.	Tseng et al. (2021);[99] China; Dietary calcium screening tool/semi-quantitative FFQ; Paper-based.	Mandarin-language FFQ (107-item); N = 83 (35.2 ± 9.3 years).	Six-item; Calcium-based: dairy products, soy products, leafy green vegetables, nuts, seafood, vitamin D rich foods.	✓ Correlation coefficients: Spearman. ✓ Kappa statistics. ✓ ICC. ✓ Sensitivity. ✓ Specificity. ✓ ROC.	▪ Fair (0.20–0.39) to moderate (0.40–0.69) relative validity. ▪ Moderate reproducibility (r = 0.40–0.69). ▪ Sensitivity: 55.6%. ▪ Specificity: 28.8%. ▪ Systematic error: reference standard and index tool share similar error structures (i.e. both are FFQs). ▪ Generalisability limited to HIV patients.

✓ = Statistical test done in validation; × = Statistical test not done in validation.

2.6 Conclusion

The development of mobile-based apps offers the opportunity for a technology-based approach to a dietary screener. Simultaneously, dairy intake in South Africa is low and a feasible solution for dairy-based nutrition education and intervention is needed. To the best of the researcher's knowledge, no dietary screening tool examining dairy intake exists for use in an adult South African population. Such a tool would provide a simple and cost-effective method to assess dairy intake in South African adults. There is a clear need for the development of such a tool, followed by the validation thereof.

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3 CHAPTER 3: THE USABILITY OF THE DAIRY DIARY

This chapter focuses on the first two objectives of the study:

- To report on the development of the Dairy Diary using the five-step best practice guidelines recommended by the International Life Sciences Institute (ILSI) Europe Dietary Intake and Exposure Task Force for reporting on technology-based dietary assessment tools (Elridge et al., 2019).
- To evaluate the usability of the Dairy Diary in South African adult respondents (consumers and nutrition professionals) using the user-friendly version of the Mobile Application Rating Scale (uMARS) (Stoyanov et al., 2016).

The article, as published, is presented below and reproduced in Annexure D.

Piderit M, White Z, Wenhold FAM. The development and usability of a web-based mobile application as a dairy intake screener for South African adults. J Dairy Res. 2022;89:453–460. https://doi.org/10.1017/S0022029922000802 (IF: 2.027).

3.1 Abstract

Paper-based dietary assessment tools such as food frequency questionnaires (FFQ) and especially dietary screeners are making way for versions that use technology. Amidst low intakes of dairy and dairy-related nutrients in South Africa and to increase public awareness thereof, we aimed to develop and evaluate the usability of an application (app) to screen for dairy intake in higher income South African adults. In a consultative process, a dairy intake screener (the Dairy Diary) was developed as an eight-item quantitative FFQ with four types of commonly consumed local dairy product, namely: milk, maas (fermented milk), yoghurt, and cheese. For each dairy product, the usual frequency of consumption and portion size per eating occasion were scored resulting in three risk classes, namely: < 1 serving daily; 1 to < 2 servings daily; ≥ 2 servings daily.

Digitalisation included product- and portion-specific graphics with linkage to risk class-relevant preliminary dairy-related guidance as part of a web-based mobile app. For the evaluation of the usability, the 26-item end-user version of the Mobile Application Rating Scale (uMARS) was used in an online cross-sectional survey (Qualtrics, April 2020). Items were scored on a five-point Likert-type scale, resulting in three final app scores. From a conveniently recruited sample of 1 102 respondents, 703 (64%; 81% female; mean age 29.8 ± 11.0 years) were retained for analysis. uMARS-informed descriptive statistics summarise the findings. The uMARS app mean objective quality score (3.9 ± 0.85), app subjective quality score (3.5 ± 0.77), app-specific score (3.6 ± 0.94), and additional question on e-portion (4.3 ± 0.78) met the minimum acceptability score of ≥ 3.0. For the subscales, the mean score for aesthetics was the highest (4.4 ± 0.82), followed by information (4.3 ± 0.90) and functionality (4.0 ± 1.33). Engagement scored lowest (3.0 ± 1.55). The Dairy Diary is a user-friendly screener for dairy intake.

3.2 Background

In South Africa, dairy intake is low (Labadarios et al. 1999; Mchiza et al., 2015) and does not meet the daily recommendations as per the South African food-based dietary guidelines (Vorster et al., 2013). Available evidence suggests the beneficial role of dairy in managing non-communicable diseases, such as heart disease and diabetes (Thorning et al., 2017; Aljuraiban et al., 2019; Guo et al., 2019; Bhupathi et al., 2020), in contributing to meeting gap nutrient intakes (Weaver, 2014), and in being a surrogate marker of diets higher in nutritional quality (Clerfeuille et al., 2013; Rice et al., 2013; Weaver, 2014).

Dietary screening (a short, focused, preliminary assessment of intake) is popular when information on total diet is not needed and when financial and/or time constraints are applicable (Gurinovic et al., 2017). Dietary screening may create awareness of poor intake, triggering a comprehensive dietary assessment (Field & Hand, 2015) and thus intervention by a nutrition professional. The FFQ is a dietary assessment tool that assesses how often food items from a predetermined list are usually consumed within a specified reference period (Rodrigo et al., 2015). In the quantitative version, portion sizes of the foods are also determined. Traditionally, dietary assessment tools have been paper-based, but these are

increasingly making way for technology-based versions in the form of web- and mobile-based apps: software apps that can be executed (run) on a mobile platform (with or without wireless connectivity) or a web-based software app tailored to a mobile platform but executed on a server (US Department of Health and Human Services, 2015).

The underlying methodology of dietary assessment is unchanged by technology (Illner et al., 2012; Sharp & Allman-Farinelli, 2014), yet technology offers the potential of improved efficiency (Hongu et al., 2011; Burrows & Rollo, 2019). Compared with traditional versions, a greater preference and satisfaction to use technology-based versions have been reported (Touvier et al., 2011; Sharp & Allman-Farinelli et al., 2014; Hutchesson et al., 2014; Timon et al., 2017; Torre et al., 2017; Burrows & Rollo, 2019). Flexibility, ease of access, reduced respondent burden, increased respondent co-operation, compliance, acceptance and greater appeal and relevance to a younger population are some of the strengths of web- and mobile-based apps (Hongu et al., 2011; Illner et al., 2012; Gurinovic et al., 2017). Limitations include high development and set-up costs, the need for secure internet access and limited use in populations who are not familiar with technology, such as the elderly (Gurinovic et al., 2017).

The initial evaluation of a dietary screener is typically in terms of usability: the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO, 2018). There is no consensus on the best tool to assess usability of mobile apps. MARS is a simple, objective tool for critically appraising the quality of health-related apps (Stoyanov et al., 2015). Because MARS requires some training and expertise, a user-friendly version, namely uMARS (Stoyanov et al., 2016), was developed with excellent internal consistency ($\alpha = 0.90$) and high α for all subscales (engagement $\alpha = 0.80$; functionality $\alpha = 0.70$; aesthetics $\alpha = 0.71$; information $\alpha = 0.78$; satisfaction $\alpha = 0.78$). The total uMARS score and each individual subscale also have good test-retest reliability (Stoyanov et al., 2016).

Accordingly, the first objective of this study was to develop a web-based mobile app (Dairy Diary) as a tool to screen for dairy intake in South African adults, and the second objective was to evaluate the usability of the Dairy Diary in two high-income subgroups (consumers and nutrition professionals) using uMARS.

3.3 Materials and Methods

The content and design of the dairy screener were compiled, reviewed, and revised in a consultative process by a working group of dietitians and nutritionists knowledgeable in consumer education related to dairy and/or dietary assessment. The dietary screener is available online at the Consumer Education Project (CEP) of Milk South Africa (https://www.dairygivesyougo.co.za/dairy-diary).

3.3.1 Study design, population and sample, and data collection tools

In a cross-sectional e-survey, data were collected by means of an online questionnaire using Qualtrics. The population were South African adults (consumers and nutrition professionals) with a high income [living standards measure (LSM) > 8] aged 19–65 years with access to a computer and/or smartphone and the internet. The LSM (LSM, 2022; http://www.eighty20.co.za/lsm-calculator/) is a widely used socioeconomic segmentation tool in South Africa for classifying consumers independent of race/ethnicity, sex, age or any other variable. Recruitment took place between March and April 2020. Participants were conveniently sampled via word of mouth and social media platforms associated with the University of Pretoria, professional dietetics and nutrition associations in South Africa (such as the Association for Dietetics in South Africa [ADSA]), and the CEP of Milk South Africa website (Dairy Gives You Go, 2022). See Figure 3.1.

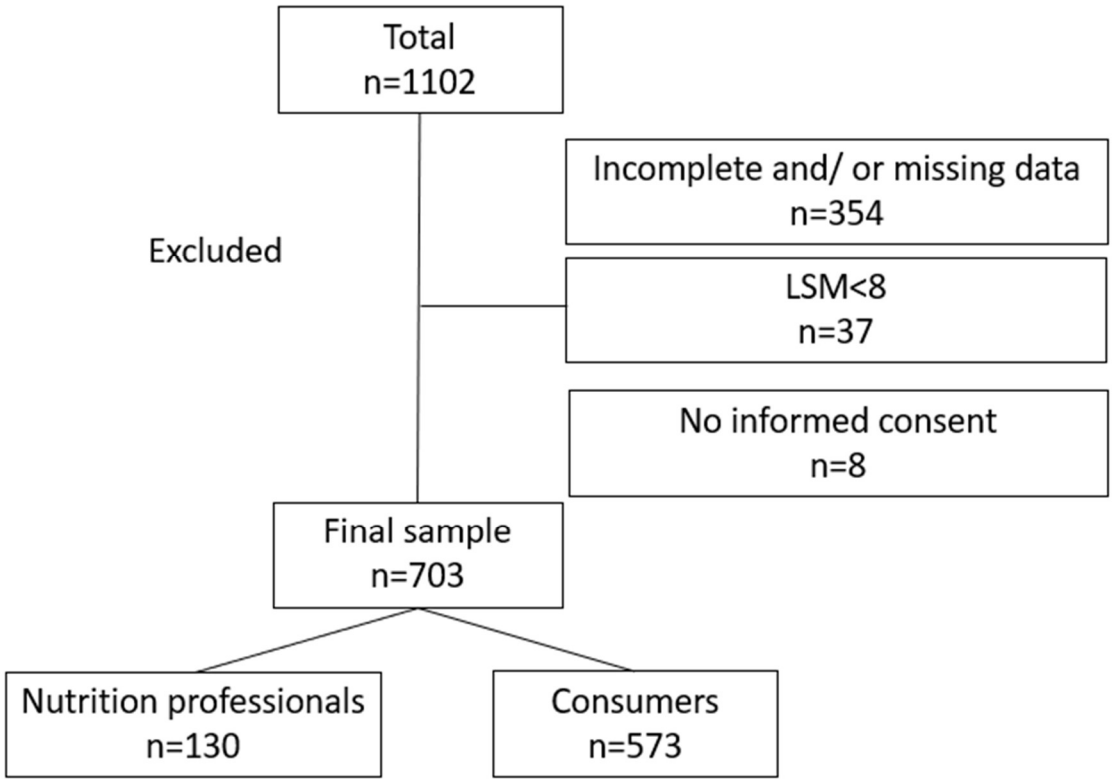

Figure 3.1: Sample for the usability study

First, participants completed the Dairy Diary, which calculates a daily serving score. Second, participants evaluated the Dairy Diary using uMARS, to which an additional question on portion sizes was added in an electronic format (e-portions). The uMARS consists of 26 questions of three scores: app objective quality (four subscales of 16 items including five items on engagement, four on functionality, three on aesthetics and four on information), app subjective quality (four items) and app-specific score (six items adjusted to include questions to assess the perceived impact of the app on the user's knowledge, attitudes and intentions to change for the target health behaviour, i.e. dairy intake) (Stoyanov et al., 2016) (see Table 3.1).

Information on demographics [age, self-reported weight and height to calculate body mass index (BMI), gender], perceived health status and mobile app usage was collected (see Table 3.2). For nutrition professionals, additional information included recommended use of apps to patients, area of practice, reason for recommending app usage and opinion on the use of mobile apps compared with traditional (paper-based) methods for dietary assessment (see

Table 3.3). A pilot study was conducted before commencement of data collection on eight participants (two nutrition professionals and six consumers). The participants of the pilot study were not included in the final analysis.

3.3.2 Data management and statistical analysis

Raw data were exported from Qualtrics in Microsoft Excel format. Data were cleaned for incomplete and/or missing responses – those with LSM < 8 and those without informed consent. To calculate BMI, self-reported weight (kg) was divided by self-reported height squared (m^2). Descriptive statistics of central tendency (means) and dispersion (SD and 95% confidence interval) were applied for demographic information, the daily serving score and uMARS data. For the latter, all items were scored on a five-point Likert-type scale (1 = inadequate; 2 = poor; 3 = acceptable; 4 = good, 5 = excellent; N/A = not applicable). Mean scores per item were reported instead of total scores as items could have been rated as not applicable. The minimum mean acceptability score for the uMARS was ≥ 3.0 (Mani et al., 2015). Data analyses were performed using Stata Release 15 (Release 15.1, College Station, TX: StataCorp LLC).

Table 3.1: The uMARS scale, subscales and items: mean and total score for the sample (n = 703)

Subscale	Item	Mean	SD
1. App Mean Objective Quality Score [a]		3.90	0.85
Engagement	Entertainment	3.23	1.38
	Interest	3.53	1.43
	Customisation	2.05	1.71
	Interactivity	2.46	1.69
	Target group	3.86	1.54
	Engagement mean score	3.03	1.55
Functionality	Performance	4.07	1.54
	Ease of use	4.13	1.36
	Navigation	3.79	1.45
	Gestural design	3.85	1.86
	Functionality mean score	3.96	1.33
Aesthetics	Layout	4.51	0.95
	Graphics	4.26	1.00
	Visual appeal	4.26	0.89
	Aesthetics mean score	4.35	0.82
Information	Quality of info	4.28	0.97
	Quantity of info	4.21	1.17
	Visual info	4.37	1.05
	Credibility of source	4.20	1.19
	Information mean score	4.27	0.90
2. App Mean Subjective Quality Score		3.49	0.77
Subjective quality	Recommend the app	3.71	1.24
	App use in one year	4.30	1.31
	Pay for app	2.27	0.99
	Overall star rating	3.69	0.72
3. App-Specific Mean Score		3.56	0.94
App-specific	Awareness	3.82	1.05
	Knowledge	3.84	1.05
	Attitudes	3.46	1.11
	Intention to change	3.44	1.14
	Help seeking	3.47	1.18
	Behaviour change	3.31	1.19
Additional question on e-portions		**4.27**	**0.78**

a Mean of four objective subscales of 16 items: engagement (5 items), functionality (4 items), aesthetic (3 items) and information (4 items).

SD = standard deviation.

Table 3.2: Demographic and background information of the study participants (n = 703)

Background Characteristics[a]			n	%
Sex	Female		568	80.8
	Consumer (n = 73)	Female	440	76.8
	Nutrition professional (n = 130)	Female	128	98.5
BMI category[b] (WHO, 2004)	Underweight		30	4.3
	Healthy weight		399	56.8
	Overweight		175	24.9
	Obese		99	14.1
How did you hear about the Dairy Diary?	Network at University of Pretoria		222	31.6
	From a dietitian/healthcare professional		150	21.3
	From a friend/colleague		109	15.5
	From a professional organisation		80	11.4
	From my company/employer		55	7.8
	On the Dairy Gives You Go website		49	7.0
	Facebook		38	5.4
How many times have you completed the Dairy Diary?	Once		664	94.5
	Twice		27	3.8
	Three times		8	1.1
	More than three times		4	0.6
How are you completing this questionnaire?	On a smartphone		380	54.1
	On a desktop/laptop		323	45.9
	On a tablet		0	0.0
In general, how is your health?	Very healthy		478	68.0
	Somewhat healthy		216	30.7
	Not healthy		9	1.3
How often do you personally use nutrition- and health-related apps?	Daily (or almost daily)		155	22.1
	Weekly		126	17.9
	Monthly		72	10.2
	Hardly ever		350	49.8

a Self-report with online questionnaire.

BMI: self-reported weight (kg) divided by self-reported height squared (m2).

b Underweight: < 18.5 kg/m2; Healthy weight: 18.5–24.9 kg/m2; Overweight: 25.0–29.9 kg/m2; Obese: > 30.0 kg/m2.

Table 3.3: Descriptive information of the nutrition professionals (n = 130)

Background Characteristic		n	%[a]
Sex	**Female**	**128**	**98.5**
Do you recommend nutrition- and health-related apps to patients/clients?	Yes	78	60.0
What area do you mostly work in?	Private practice	60	46.2
	Government	23	17.7
	University/tertiary education	12	9.2
	I no longer practice as a dietitian	9	6.9
	Corporate/food industry	8	6.2
	Research	5	3.9
	Community setting	4	3.1
	Other[b]	9	6.9
Why do you recommend your patients/clients use health- and nutrition-related apps?[c]	For self-monitoring	65	50.0
	To increase awareness	53	40.8
	For motivation and extra support	47	36.2
	For goal setting	40	30.8
	As an information resource	39	30.0
	I do not recommend apps	26	20.0
	As a dietary assessment tool	24	15.5
	To reduce time during consultations	1	0.8
How do you know which health- and nutrition-related apps to recommend?[c]	From personal use of apps	86	66.2
	From recommendations from other dietitians and healthcare professionals	71	54.6
	From recommendations from my patients/ clients	29	22.3
In your opinion, how do mobile apps compare with traditional (paper-based) methods for dietary assessment?	Mobile apps are better than traditional methods for dietary assessment	48	36.9
	Mobile apps are equivalent to traditional methods for dietary assessment	61	46.9
	Mobile apps are worse than traditional methods for dietary assessment	21	16.2

a Percentage of affirmative.

b Includes unemployed, food service management, medical/pharmaceutical representative, clinical, and non-profit organisations.

c Participants could select more than one option.

3.3.3 Ethical approval

The study was approved by the University of Pretoria Faculty of Health Sciences Research Ethics Committee (705/2018). Electronic informed consent was obtained and all information was confidential. Participants voluntarily provided contact details to enter a random lucky draw to receive one of three online vouchers.

3.4 Results

Results of this study are described using the ILSI Europe Dietary Intake and Exposure Task Force Best Practice Guidelines for reporting on dietary intake assessment tools using new technologies (Elridge et al., 2019). Steps 1–4 are used for the development and Step 5 for the usability of the dairy intake screener.

3.4.1 Step 1: Purpose of the tool

The main purpose of the Dairy Diary is to screen for and identify consumers at risk of low dairy intake. The dietary screener is for direct consumer use. South African adult consumers of higher income and nutrition professionals were the primary target group in this study.

3.4.2 Step 2: Main measurement features of the tool

A quantitative FFQ format was chosen for the Dairy Diary. Participants were prompted to consider habitual dietary intake of dairy products, usually consumed as a snack or meal, eaten at or away from home, and/or eaten alone or as part of a meal over the previous month. Assisted data entry allowed the user to select frequency of consumption and portion size from predefined options. Additional items could not be entered into the Dairy Diary. For each dairy product, customisation included visual representation of portion sizes [e.g. cup measures for milk, maas (a widely consumed fermented milk in South Africa), yoghurt and soft cheese but slices for hard cheese], supplemented with text indicating various ranges in volumes and cup measures (up to ½ cup, ½–1 cup, more than 1 cup) (see Figure 3.2). The user was able to return to previous screens as necessary. Once digitalised, graphic enhancement was added. No further supplementary information on physical activity or dietary supplementation was collected.

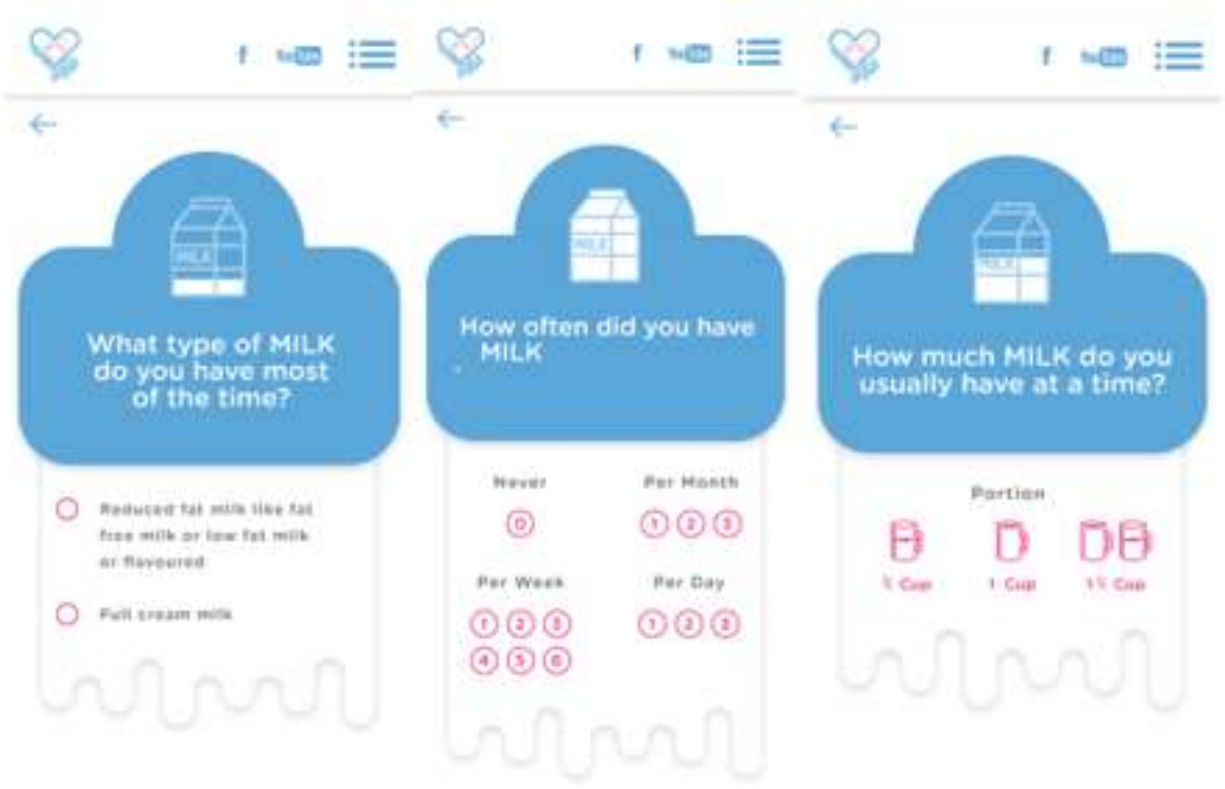

Figure 3.2: Example images of the type, frequency of consumption and amount (portion sizes) in the Dairy Diary

Food list: The food list is the backbone of the FFQ (Cade et al., 2004; Shim et al., 2014). Three dairy products specified in the relevant South African food-based dietary guideline ("Have milk, maas and yoghurt every day"; Vorster et al., 2013), plus cheese, all represented generically, formed the four dairy products and basis of the FFQ. Additional data were collected about the form of dairy product consumed: milk (reduced fat or full cream), maas (reduced fat or full cream), yoghurt (plain or flavoured), and cheese (hard or soft) (see Figure 3.2). This resulted in a final food list of eight items.

Frequency score: For each dairy product, the frequency (number of times) of consumption was assessed in four frequency categories: never, per day (0–3 times), per week (1–6 times), or per month (1–3 times). Each frequency category was converted into a daily intake amount. To score daily intake amounts, the frequency per day was defined by a factor of 1 (i.e. if the user indicated drinking milk twice a day, the factor is 2/1). To score weekly amounts, the frequency per week was defined by a factor of 7 (i.e. if the user indicated eating yoghurt three times per

week, the factor is 3/7). To score monthly amounts, the frequency per month was defined by a factor of 30.417: the average number of days per month in a calendar year (i.e. if the user reported consuming maas twice per month, the factor is 2/30.417).

Serving score: The portion size consumed per eating occasion for each dairy product was shown as text and with quantifiable graphics, indicated as little, medium, or lots, defined as 50%, 75%, and 100% or more of a reference serving, respectively. The CEP of Milk SA defines the reference serving size of dairy as an amount containing 300 mg of calcium. For milk and maas, portions were scored as 0.5 for intake up to ½ cup, 0.75 for intakes ½–1 cup, or 1.0 for intakes more than 1 cup. For yoghurt, portions were scored as 0.5 for intakes of 1 small tub (100 ml), 0.75 for intakes of 1 cup, or 1 for intakes of more than 1 cup. For hard cheese, portions were scored as 0.5 for 1 slice (up to 20 g), 0.75 for 2 slices (20–40 g), or 1.0 for 3 slices (more than 40 g). For soft cheese, portions were scored as 0.5 for up to ¼ tub (60 g), 0.75 for ¼–½ tub (60–125 g), or 1.0 for intakes of more than 1 tub (125 g) (see Table 3.4).

Daily serving score: A dairy product score was calculated for each dairy product by multiplying the frequency score by the portion score. The daily serving score was the sum of the dairy product scores (Table 3.4). The daily serving score was classified into three risk classes (< 1 serving daily, 1 to < 2 servings daily, or ≥ 2 servings daily), guided by recommendations to consume at least 2 servings of dairy per day (Weaver, 2014). Maximum theoretical daily serving scores for milk, maas, yoghurt and cheese are 4.4, 2.5, 2.5 and 2.7, respectively. The theoretical total maximum score is 12.24 (see Table 3.5).

Table 3.4: Calculations underpinning the daily serving score

Dairy product	Items in the Dairy Diary	Method of eating/ drinking	Frequency score: A[b] How often per day?				Serving score: B How much per eating occasion?			Dairy product[c] score = A × B
			Never	Per day	Per week	Per month	Little (Serving score: 0.5)	Medium (Serving score: 0.75)	Lots (Serving score: 1.0)	
Milk	Reduced fat[a] Full cream	As a drink on its own	0	Once: 1/1 Twice: 2/1 Three times: 3/1	Once: 1/7 Twice: 2/7 Three times: 3/7 Four times: 4/7 Five times: 5/7 Six times: 6/7	Once: 1/30.417 Twice: 2/30.417 Three times: 3/30.417	Up to ½ cup	½–1 cup	> 1 cup	1
		In tea and coffee	0				< 30 ml	30–50 ml	> 50 ml	
		Cereal/porridge	0				< ½ cup	½–1 cup	> 1 cup	
		Flavoured milk	0				< ½ cup	½–1 cup	> 1 cup	
		Milky dessert, e.g. custard	0				< ½ cup	½–1 cup	> 1 cup	
Maas	Reduced fat[a] Full cream	N/A	0				< ½ cup	½–1 cup	> 1 cup	2
Yoghurt	Flavoured Plain	N/A	0				1 small tub: 100 ml	1 cup: 200–250 ml	> 1 cup: 250 ml	3
Cheese	Hard	N/A	0				1 slice < 20 g	2 slices: 20–40 g	3 slices > 40 g	4
	Soft	N/A	0				< ¼ cup (60 g)	> ½ tub: 60–125 g	> 1 tub (125 g)	
Daily serving score[d]										**=1+2+3+4**

a Includes fat-free and low fat.

b Reported frequency of intake converted to intake per day. Examples: To score *daily* amounts, the reported frequency of intake per day was divided by a factor of 1 (i.e. if the user indicated drinking milk twice a day, the daily amount is 2/1). To score *weekly* amounts, the reported frequency of intake per week was divided by a factor of 7 (i.e. 7 days per week i.e. if the user indicated eating yoghurt three times per week, the daily amount is 3/7). To score *monthly* amounts, the reported frequency of intake per month was divided by a factor of 30.417: the average number of days per month in a calendar year (i.e. if the user reported consuming maas twice per month, the daily amount is 2/30.417).]

c Dairy product score: for each dairy product, frequency score (A) multiplied by serving score (B).

d Daily serving score: sum of the dairy product scores (1–4).

Table 3.5: The daily serving score [a] of the study participants (n = 703)

Dairy product	Mean intake[b]	SD[c]	Min	Max	95% CI[d]
Milk	1.00	0.74	0.0	4.71	0.95; 1.06
Maas	0.10	0.21	0.0	2.50	0.05; 0.91
Yoghurt	0.41	0.51	0.0	3.75	0.38; 0.45
Cheese	0.53	0.55	0.0	3.67	0.49; 0.57
Daily serving score[a]	2.01	1.37	0.0	12.24	1.91; 2.11

a Daily serving score: sum of the four dairy product scores, calculated for each dairy product by multiplying frequency score by portion score.

b Mean intake: Average dairy product score for sample (n = 703).

c SD: standard deviation.

d CI: confidence interval.

3.4.3 Step 3: Platform/technology of the tool

The final content was converted to a digital version, executed on a web browser from an internet-connected device such as a smartphone, tablet, laptop, or computer. This platform was deemed appropriate for the population as data costs in South Africa are high, which may deter users from downloading the screener in a mobile app format. The development costs of a mobile app were another consideration.

3.4.4 Step 4: Customisation features of the tool

A predetermined list of local dairy products with household measures (supplemented with images) formed the basic customisation features of the screener. Feedback included preliminary nutritional education (Dairy Tips) linked to the participant's daily serving score. This consisted of consumer-friendly, targeted dairy-related information to support and encourage increased dairy intake or to maintain current intake. No further customisation features were available.

3.5 Discussion

South Africa leads the number of mobile app downloads in Africa (GSMA, 2019). Approximately 62% of South African consumers own a connected mobile device and 21% use the device to access healthcare information (Nkume, 2017). Considering the low dairy intakes in South Africa and the growing trend of smartphone usage, screening for dairy intake may

increase awareness and consumption of dairy, thereby initiating, motivating, and driving behaviour change to raise awareness of and improve low dairy intakes. Thus, we have described the development of the Dairy Diary, a web-based mobile app that includes an eight-item food list with portion size to calculate total daily dairy intake. Further to this, we evaluated the usability of the Dairy Diary using uMARS (Stoyanov et al., 2016).

While many dietary screeners exist to assess for calcium intake in adults (Magarey et al., 2014), few dairy intake screeners exist with a food only focus (as opposed to nutrient and/or food focus). In 1995, the dairy questionnaire was developed as a traditional (paper-based) quantitative screener to estimate the calcium intake from dairy products in young adults (27–29 years) (Welten et al. 1995). The Dairy Questionnaire, also in a quantitative FFQ format, shows moderate to good reliability and is considered valid for the assessment of calcium intake from dairy products. Other dairy intake screeners by Angbratt and Möller (1999), Gans et al. (2006), and Goldbohm et al. (2011) also assessed both calcium and dairy intake.

In Southern Africa, to the author's knowledge, dairy intake screeners do not exist. Thus, the Dairy Diary is an original, novel and local technology-based dairy intake screener. With growing interest in technology-based dietary screening tools, evaluating the usability of dietary screeners is essential. Results from this study showed that the three mean scores in uMARS each met the minimum acceptable score of ≥ 3.0 (Mani et al., 2015). The app objective quality mean score was the highest scoring domain, followed by the app-specific mean score, and app subjective quality score. The functionality score was the highest and the engagement score was the lowest. This indicates the user's preference towards favouring input and participation when utilising the app. The same pattern of high functionality and low engagement has been reported in other studies using uMARS (LeBeau et al., 2019; Davalbhakta et al., 2020). LeBeau et al. (2019) evaluated 25 mobile apps used by occupational therapists, and Davalbhakta et al. (2020) evaluated 63 Covid-19 related apps. In both studies, high functionality and low engagement scores were reported.

Participants scored the layout of the Dairy Diary the highest, followed by visual information. This suggests that participants value the aesthetic and visual appeal of the dietary screener, implying participants desire the opportunity to adapt and personalise the dietary screener, an

observation which may be particularly relevant to the nutrition professional. In this study, participants scored high on the subscales of information, quality of information, quantity of information and credibility of the source. To the contrary, when evaluating nutrition-related apps in Brazil, Braz and Lopes (2018) found that mobile apps were not based on reliable sources of information. This was supported by Byambasuren et al. (2019) with 16% of Australian general practitioners reporting a lack of trustworthy sources as a barrier to prescribing apps in practice.

Customisation and willingness to pay for the apps scored lowest, suggesting that users may be less inclined to use the app if payment was requested. Accordingly, future considerations to enhance user participation may include more customisation options for the Dairy Diary to tailor to the user's preferences. Future research may also evaluate the usability of the Dairy Diary in different age and gender groups. In addition, planners of public health initiatives may benefit from the outcome of the Dairy Diary to screen for low dairy intakes among the general public. It may also be valuable to evaluate the usability of a traditional (pen and paper) version of the Dairy Diary in these different populations.

For nutrition professionals, the Dairy Diary may be a simple and practical tool to screen for low dairy intakes, driving dairy-related nutrition education. Such a tool may serve as a trigger into the nutrition care process for more comprehensive dietary assessment. Including apps in dietetic practice could enhance the efficiency and quality of nutrition care and counselling, supporting that nutrition professionals play a leading role in the development of such dietary screeners (Chen et al., 2018). For this reason, the study population included a subgroup of nutrition professionals in South Africa.

To the authors' knowledge, nutrition- and health-related mobile app use among South African nutrition professionals is unknown. In the present study, 60% of nutrition professionals recommend app usage to patients, with two-thirds basing their recommendation from personal use of the apps. Higher proportions (79%) of mobile app usage have been reported among American dietitians (Sharman & Ashby, 2015), as well as in the Clinician Apps Survey (85%: Karduck & Chapman-Novakofski, 2018). Furthermore, Sauceda et al. (2016) reported that 83% of healthcare providers recommend nutrition- or health-related apps to patients.

Lower mobile app recommendations have been reported in an international survey of healthcare professionals from 73 countries (46%: Vasiloglou et al., 2020). Canadian dietitians (57%: Lieffers et al., 2014), Irish dietitians (42%: Timon, 2018) and sports dietitians in Australia, Canada, New Zealand, United States and the United Kingdom (32%: Jospe et al., 2015) likewise have shown lower usage.

In South Africa, mobile data costs are among the highest in the world (Moyo & Munoriyarwa, 2021), despite 83% smartphone penetration in 2018, which is nearly double that of 2016 (ICASA, 2019). At the same time, internet and fibre-to-the-home/building internet subscriptions increased by 42% and 279%, respectively (ICASA, 2019). High mobile data costs may potentially explain lower app recommendation by nutrition professionals in South Africa compared with other countries, despite increased internet access.

Jospe et al. (2015) found that dietitians describe apps as “better” (47%) or “equivalent” (41%) to traditional dietary assessment methods. In our study, results were similar with 37% and 47% of dietitians reporting that mobile apps are “better” or “equivalent to” traditional methods for dietary assessment, respectively. The generalisability of this study may be considered limited in that three-quarters of consumers and almost all of the nutrition professionals were female. Traditionally, the nutrition profession is known to be mostly female, as supported by the ADSA membership profile with 97.1% being female (ADSA, 2022). The evaluation of the usability may also be different in lower LSM groups. Thus, it may be pertinent to evaluate the usability of the Dairy Diary in other populations.

3.6 Conclusion

In conclusion, as evaluated by uMARS, the Dairy Diary is a technology-based, user-friendly dairy intake screener. For a dietary screening tool to be of value, its performance needs to be assessed in terms of reliability and validity. If reliable and valid, such a screener may contribute to the quick assessment of dairy intake. Future validation studies of the Dairy Diary are recommended.

3.7 Acknowledgement and Conflict of Interest

The development of the Dairy Diary was supported by the CEP of Milk SA. The Nestlé Nutrition Institute of Africa (NNIA) is acknowledged as part funders of this study. The CEP of Milk South Africa and NNIA were not involved in the theoretical development of the algorithm to calculate the dairy serving score. Prof. Piet J Becker is acknowledged for statistical support.

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4 CHAPTER 4: THE COMPARATIVE VALIDITY OF THE DAIRY DIARY

This chapter focuses on the third and fourth objectives of the study:

- To determine the test-retest reliability of the Dairy Diary among dietetics/nutrition students with two administrations of the dairy intake screener on an individual level
- To determine the test-retest reliability of the Dairy Diary among dietetics/nutrition students with two administrations of the dairy intake screener on a group level.
- To determine the comparative validity of the Dairy Diary (i.e. index test) against three-day weighed food records (i.e. reference standard) among dietetics/nutrition students.

For the validity study, the researcher was guided by the Standards for Reporting Diagnostic Accuracy Studies (STARD) checklist (Cohen et al., 2016). The full manuscript, as submitted to *Food Science and Nutrition* (IF 3.553) in July 2023 is presented below.

"DAIRY INTAKE SCREENER AS WEB-APPLICATION IS RELIABLE AND VALID"

Piderit M.C., White Z., Becker P.J., Wenhold F.A.M.

4.1 Abstract

The Dairy Diary is a user-friendly web-based dairy intake screener. The reliability and validity thereof are unknown. We aimed to evaluate the screener in terms of test-retest reliability and comparative validity.

In a diagnostic accuracy study, a purposefully recruited sample of 79 (age: 21.6 ± 3.8 years) undergraduate dietetics/nutrition students from three South African universities completed three non-consecutive days of weighed food records (reference standard) within a seven-day period (comparative validity) followed by two administrations, two weeks apart, of the screener (index test) (reliability). For four dairy product serving scores (PSSs) and the summative dairy daily serving scores (DSSs) of the screener and the food records, t-tests, correlations, Bland–Altman, Kappa, McNemar's, and diagnostic accuracy were determined.

For reliability, mean PSSs and DSSs did not differ significantly ($P > 0.05$) between the screener administrations. Mean PSSs were strongly correlated for milk ($r = 0.69$; $P < 0.001$), maas (fermented milk) ($r = 0.72$; $P < 0.001$), yoghurt ($r = 0.71$; $P < 0.001$), and cheese ($r = 0.74$; $P < 0.001$). For DSSs, Kappa was moderate ($\kappa = 0.45$; $P < 0.001$). Non-agreeing responses suggest symmetry ($P = 0.334$). For validity, the PSSs of the screener and food records were moderately correlated [milk ($r = 0.30$; $P = 0.0129$), yoghurt ($r = 0.38$; $P < 0.001$), and cheese ($r = 0.38$; $P < 0.001$)], with $\kappa = 0.31$ ($P = 0.006$) for DSS. Bland–Altman analyses showed acceptable agreement for DSSs [bias: −0.49; 95%CI): −0.7 to −0.3)]. Categorised DSSs had high sensitivity (81.4%) and positive predictive value (PPV; 93.4%), yet low specificity (55.6%) and negative predictive value (NPV; 27.8%). The area under the receiver operating characteristic curve (0.7) was acceptable.

The Dairy Diary is test-retest reliable and has moderate comparative validity to screen for dairy intake of groups.

Keywords: dietary screener; the Dairy Diary; dairy intake screener; validity; reliability.

4.2 Introduction

Dietary assessment forms part of nutrition assessment, which includes the interpretation of dietary, laboratory, anthropometric and clinical data to determine the nutritional status of individuals or populations (Field & Hand, 2015). Food frequency questionnaires (FFQs), 24-hour dietary recalls, and food records are used for comprehensive diet assessment (Bailey, 2021).

When time and other resource constraints limit comprehensive dietary assessment, screening may be favoured. Nutrition screening identifies an individual who is malnourished or at risk of malnutrition to determine whether further comprehensive nutrition assessment is required (Mueller et al., 2011). Despite overlaps, nutrition screening is separate from and different to nutrition assessment (Field & Hand, 2015; Swan et al., 2017) preceding the latter to serve as a trigger into the nutrition care process for a more comprehensive assessment (Charney, 2008; Field & Hand, 2015; Swan et al., 2017). Dietary screening is typically achieved using short questionnaires such as screeners (Charney, 2008). Such tools may take the basic form of an

FFQ that is adapted to be interpretable, for example, through a scoring system to identify the presence or absence of dietary risk. Dietary screeners should be cost-effective, easy and quick to use, with at least a high sensitivity for early detection of nutrition risk. However, in resource-limited settings, high specificity (i.e. fewer false positives) may be favoured in some instances (Trevethan, 2017).

Already a decade ago, individuals were within arm's reach of a mobile phone 50% of the time (Dey et al., 2011). This potentially drove the trend to access health- and nutrition-related information via mobile applications (apps) (Krebs & Duncan, 2015; Chen et al., 2018). In South Africa, mobile app downloads are high (Nkume, 2017). The uptake of mobile technology highlights a significant opportunity to affect health behaviour (Zhao et al., 2016), with technology-based dietary screeners gaining favour over traditional (paper-based) versions (Lucassen et al., 2021).

Despite consistent evidence of the positive role of dairy for health (Weaver, 2014), dairy is the most commonly deficient food group in South Africa (Mchiza et al., 2015). Internationally, dairy intake screeners have been developed and/or validated for populations in North America (Blalock et al., 2003; Gans et al., 2006; Sebring et al., 2007; Hacker-Thompson et al., 2009; Gilsing at el., 2018), Australia (Hodge et al., 2000; Clover et al., 2007; Gadowski et al., 2020), Asia (Park et al., 2013; Tseng et al., 2021), the Netherlands (Welten et al., 1995; Gans et al., 2006; Goldbohm et al., 2011; De Rijk et al., 2021), and Poland (Martela et al., 2019), yet few are technology-based (Hodge et al., 2000; Gans et al., 2006; Hacker-Thompson et al., 2009; De Rijk et al., 2021). Neither a validated nor a technology-based dairy intake screener is available in South Africa.

Thus, the aim of the Dairy Diary was to screen for dairy intake at an individual level and a group level. The development has been described and the usability thereof established (Piderit et al., 2022). The reliability and validity of the dairy intake screener remain, however, unknown. We thus aimed to assess the agreement between the Dairy Diary (index test; screener) and three-day weighed food records (reference standard) in dietetics/nutrition students in South Africa to evaluate comparative validity (Gleason et al., 2010). Since reliability is a prerequisite for validity (Gleason et al., 2010), we included test-retest reliability

assessment, which was defined as the reproducibility of the Dairy Diary scores when administered twice to the same participants.

4.3 Materials and Methods

4.3.1 The Dairy Diary: Index test

The Dairy Diary is a self-administered dietary screener with the structure of a quantitative FFQ, developed as a web-based mobile app and accessible via an internet-enabled smartphone, tablet, laptop or computer (https://www.dairygivesyougo.co.za/dairy-diary). The screener focuses on four commonly consumed dairy products in South Africa, each with two forms: milk (reduced fat or full cream), a local fermented milk named maas (reduced fat or full cream), yoghurt (plain or flavoured), and cheese (hard or soft), resulting in an eight-item food list. Reduced fat included fat-free and low fat dairy products. A PSS is calculated for each dairy product. The DSS is the sum of the four PSSs. Guided by recommendations to consume at least 2 servings of dairy per day (Weaver, 2014), the DSS is classified into two categories: < 2 servings daily or ≥ 2 servings daily.

4.3.2 Three-day weighed food records: Reference standard

Food records were chosen as the reference standard, having an independent error structure compared with the FFQ format of the index test (Gleason et al., 2010). Using a digital scale and standardised template, participants completed three days of weighed food records (FR1, FR2, FR3) on two non-consecutive weekdays and one weekend day within a seven-day period. Participants were provided with written and audio-visual instruction and demonstration (MP4 video) on keeping a food record, including the avoidance of changes in habitual diet; the immediate recording of all foods, beverages and supplements consumed in a full 24-hour period; and the weighing of non-edible parts using the tare/zero function on the scale and providing indication thereof. For composite dishes, participants were asked to document and submit all ingredients and preparation methods.

4.3.3 Study design

The reporting of this diagnostic accuracy study to assess comparative validity was guided by the STARD checklist (Cohen et al., 2016). The screener was further assessed in terms of test-retest reliability.

4.3.4 Sample size, recruitment and study population

Sample size was calculated using nQuery (version 8.3.0.0). For an assumed proportion of 60% of the population meeting dairy intake recommendations of ≥ 2 servings per day in the three-day weighed food records, a sample of at least 78 would have 90% power to reject the null hypothesis.

Recruitment took place between April 2020 and September 2021. Participants were conveniently recruited from an eligible population of 168 undergraduate dietetics/nutrition students from three universities in three provinces of South Africa (University of the Free State, University of Pretoria, and North-West University). Participants were independently recruited by lecturers at each university in contact sessions (remotely due to Covid-19 or in-person). Inclusion criteria included access to a computer and/or smartphone and internet. Data cleaning removed participants with incomplete three-day food records (n = 1). A final sample of 79 participants (47%) (first year: n = 11; second year: n = 40; third year: n = 28) was retained for analyses (Figure 4.1).

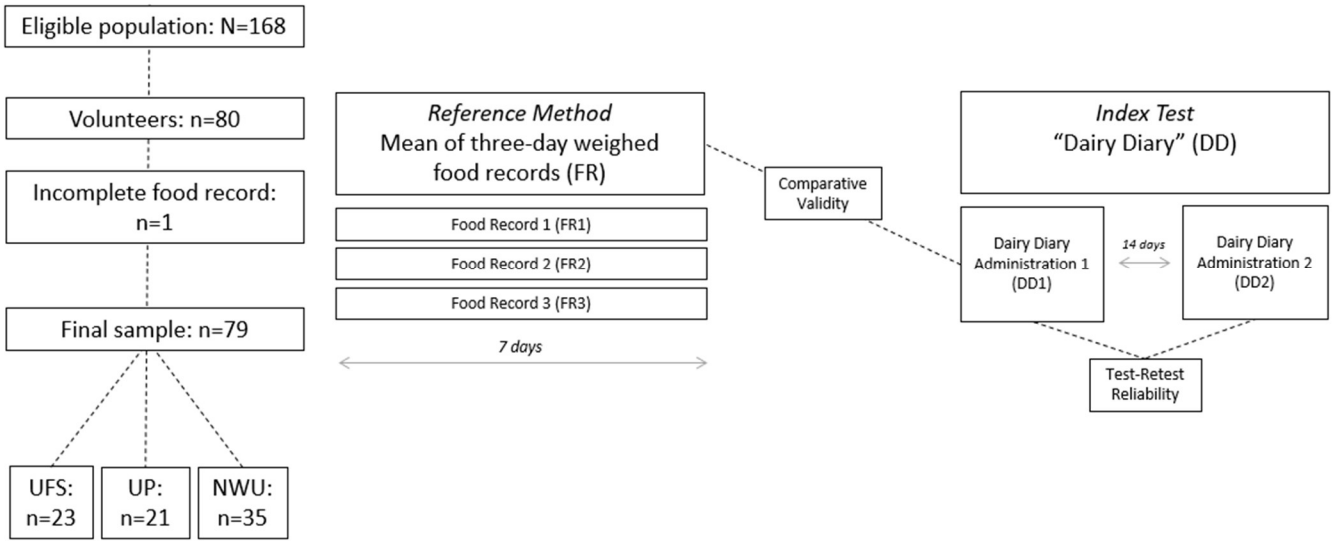

Figure 4.1: Flow diagram of study

UFS: University of the Free State; UP: University of Pretoria; NWU: North-West University.

FR: mean of the three days of food records; FR1: food record 1; FR2: food record 2; FR3: food record 3.

DD: mean of the two administrations of the Dairy Diary; DD1: first administration of the Dairy Diary; DD2: second administration of the Dairy Diary.

4.3.5 Test-retest reliability

Test-retest reliability was evaluated by comparing the PSSs of each dairy product and the DSSs achieved in the first administration of the screener (DD1) with the corresponding scores in the second administration (DD2). Aligned to Magarey et al. (2014), a time interval of two weeks was chosen between the two administrations (Figure 4.1). To minimise recall bias during the completion of the screener, data collection of the food records took place prior to the two administrations of the screener. An oral instruction (MP4 video) was provided to participants. Data were collected via Qualtrics, which is a secure, web-based survey tool that is inter-connected to the online screener. Before the first administration, information on demographics (e.g. age, self-reported weight and height, and sex), perceived health status, and mobile app usage was collected. To further reduce respondent memory bias, the final score of the screener (i.e. DSSs of DD1) was automatically blinded to participants to not influence the subsequent administration (Gleason et al., 2010).

4.3.6 Comparative validity

Comparative validity was determined by comparing the DSSs and PSSs from the first administration of the screener (DD1) to the mean DSSs and corresponding PSSs of the three-day weighed food records. We used the first administration of the Dairy Diary to reduce recall bias from previous exposure to the dietary screener (Figure 4.1). The mean time interval between the completion of food records and the first administration of the screener was 13.1 days (minimum–maximum: 3–41 days). It was assumed that the usual intake of dairy was not seasonal.

4.3.7 Ethical approval and informed consent

The study was approved by the University of Pretoria Faculty of Health Sciences Research Ethics Committee (705/2018), the North-West University Health Research Ethics Committee (NWU-00461–19-S1), and the University of the Free State Department of Human Nutrition and Dietetics. Informed consent at each data collection point, assurance of confidentiality, and blinding of recruiters (lecturers) to participation were included. Participants voluntarily provided contact details for individual feedback on their personal DSSs.

4.3.8 Data management

For the dairy intake screener, data from Qualtrics were exported in Microsoft Excel format and cleaned for incomplete responses. The body mass index (BMI) (kg/m^2) was calculated as self-reported weight (kg) divided by self-reported height squared (m^2).

For comparison of the PSSs and DSSs of the food records and screener, the following was done: From the food records, raw data on recorded portion size of dairy product consumed (milk: mL; maas, yoghurt and cheese: g) were captured in Microsoft Excel and added per day. These quantities were converted into daily serving equivalents using a reference serving of 250 mL for milk, 250 mL for maas, 200 mL for yoghurt, 30 g for hard cheese (e.g. cheddar, gouda and mozzarella), and 60 mL for soft cheese (e.g. cottage cheese and ricotta cheese). These quantities correlated with amounts containing 300 mg of calcium (US Department of Agriculture & US Department of Health and Human Services, 2020).

The PSSs for each dairy product was summed to calculate the food record PSSs and DSSs. This was repeated for each of the three food records. The mean of the PSSs and DSSs of the three food records were calculated and DSSs were categorised as either < 2 servings daily or ≥2 servings daily. Dairy products contribute 60% (Van Rossum et al., 2020) to 75% (Cormick & Belizan, 2019) of dietary calcium intake. Considering non-dairy food sources of calcium as contributors to meeting calcium requirements, we categorised dairy intake of ≥ 2 servings per day as adequate for this study.

For quality control, data from food records were captured in Microsoft Excel by the researcher and an independent research assistant – both registered dietitians with post-graduate qualifications applying preset coding rules. This was followed by automated conversion of dairy product volumes to PSSs and DSSs. Cross-checking of data included conditional formatting in Microsoft Excel to automatically alert for data capturing differences, verified by the researcher.

4.3.9 Statistical analysis

Statistical analyses were performed with Stata (Release 17.0, College Station, Texas; StataCorp LLC; 2021). A p-value of < 0.05 was considered statistically significant. Background characteristics were described. For reliability and validity assessment, multiple statistical analyses were performed (Lombard et al., 2015), including mean differences, paired t-tests, and Pearson rank correlations for continuous data, and kappa statistic for categorical data. For test-retest reliability, McNemar's test for symmetry was additionally performed on categorised DSSs. For validity assessment, agreement between DSSs of DD1 and mean DSSs of the three food records was verified with Bland–Altman plots. Sensitivity, specificity, predictive values, odds ratios, and receiver operating characteristics (ROCs) were used to quantify the diagnostic ability of the categorised DSSs of the Dairy Diary.

Correlation strength was described as poor ($r < 0.2$), moderate ($r = 0.2–0.6$) and strong ($r > 0.6$) (McNaughton et al., 2007; Schumacher et al., 2016). Strength of agreement for kappa was described as poor ($\kappa < 0$), slight ($\kappa = 0.01–0.2$), fair ($\kappa = 0.21–0.40$), moderate ($\kappa = 0.41–0.60$), strong ($\kappa = 0.61–0.80$), and almost perfect ($\kappa = 0.81–1.0$) (Landis & Koch, 1977). For Bland–Altman analyses, a clinically relevant *a priori* acceptable level of error (Hanneman,

2008) was defined as 0.5 dairy servings (i.e. 75% of the recommended dairy intake of ≥ 2 servings per day). For ROC, the area under the curve was 1.0 for a perfect test and 0.5 for a poor outcome (Soreide, 2009).

4.4 Results

4.4.1 Description of participants

From a total of 80 volunteers, 79 (98.8%) participants completed three-day weighed food records and two administrations of the screener (Figure 4.1). Participants had a mean ± standard deviation (SD) age of 21.6 ± 3.8 years and BMI of 22.7 ± 3.1 kg/m^2. Most participants (98.7%) were female and 78.5% had a healthy (18.5–24.9 kg/m^2) BMI (WHO, 2004). Most participants (62.0%) completed the screener on a smartphone and almost two-thirds (58.2%) reported being "very healthy" (Table 4.1).

Table 4.1: Demographic information of study participants (n = 79)

Background characteristic		**n**	**%**
Sex	**Female**	78	98.7
How did you complete the Dairy Diary?	**On a desktop/laptop**	29	36.7
	On a smartphone	49	62.0
	On a tablet	1	1.3
In general, how is your health?	**Very healthy**	46	58.2
	Somewhat healthy	32	40.5
	Not healthy	1	1.3

4.4.2 Test-retest reliability

When comparing DD1 and DD2, there were no significant differences between all the corresponding PSSs [milk (P = 0.663), maas (P = 0.342), yoghurt (P = 0.866), and cheese (P = 0.823)] as well as DSSs (P = 0.679) (see Table 4.2). For all four dairy products, the correlation coefficients between the first and second administration for the PSSs were strong and statistically significant ($r > 0.6$; $P < 0.001$). The Kappa coefficient indicated moderate

agreement between categorised DSS (P < 0.001). In relation to the categorised DSS, the McNemar test showed symmetry (P = 0.334).

Table 4.2: Test-retest reliability of components of the Dairy Diary (n = 79)

Dairy Diary component		Scores			Reliability indicators		
		DD1 Mean ± SD	DD2 Mean ± SD	Mean difference	P-value[a]	*r*	P-value[d]
PSSs	**Milk**	0.75 ± 0.55	0.77 ± 0.49	−0.22	0.663	0.69[b]	< 0.001
	Maas	0.01 ± 0.02	0.03 ± 0.21	−0.22	0.342	0.72[b]	< 0.001
	Yoghurt	0.25 ± 022	0.25 ± 0.22	0.00	0.866	0.71[b]	< 0.001
	Cheese	0.49 ± 0.43	0.50 ± 0.44	−0.01	0.823	0.74[b]	< 0.001
DSS, continuous		1.50 ± 0.82	1.53 ± 0.87	0.02	0.675	0.68[b]	< 0.001
DSS, categorised						0.45[c]	< 0.001

DD1: first administration of the Dairy Diary; DD2: second administration of the Dairy Diary; Mean difference: DD1 – DD2

a Paired t-test; b Pearson; c Kappa; d Level of significance for *r*.

4.4.3 Comparative validity

When comparing DD1 and food records, there were significant differences (P < 0.05) in mean intakes for all dairy products and the DSSs (see Table 4.3). The Pearson correlation coefficients were significant (P < 0.05 for all) and moderate for milk (*r* = 0.30), yoghurt (*r* = 0.38) and cheese (*r* = 0.38). The Kappa coefficient was fair for DSS (κ = 0.31).

Agreement between the first administration of the screener and food records was assessed by Bland–Altman analyses. Figure 4.2 shows plots for the PSSs for milk, yoghurt and cheese. No plot could be presented for maas due to lack of variation in intake. For DSS, Bland–Altman analyses showed acceptable agreement (bias: −0.48; 95% CI: −0.7 to −0.3), yet considerable imprecision.

Table 4.3: PSS and DSS of the Dairy Diary compared with the food records (n = 79)

Components of dairy intake		Scores					Validity indicators		
		Dairy Diary	Food records				P-value[c]	*r*	P-value[f]
		DD1	FR1	FR2	FR3	FR			
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD			
Milk	PSS[a]	0.77 ± 0.60	–	–	–	0.48 ± 0.40	< 0.001	0.30[d]	0.0129
Maas	PSS[a]	0.00 ± 0.00	–	–	–	0.00 ± 0.00	< 0.001	No estimate possible: lack of variation	
Yoghurt	PSS[a]	0.22 ± 0.41	–	–	–	0.13 ± 0.16	< 0.001	0.38[d]	0.0005
Cheese	PSS[a]	0.42 ± 0.60	–	–	–	0.20 ± 0.23	< 0.001	0.38[d]	0.0007
DSS[b], continuous		1.51 ± 0.88	1.02 ± 0.88	1.05 ± 0.88	0.97 ± 1.03	1.01 ± 0.71	< 0.001	0.30[d]	0.0073
DSS[b], categorised		–	–	–	–	–	–	0.31[e]	0.0057

DD1: first administration of the Dairy Diary; FR: Mean PSSs and DSSs for three food records: (FR1 + FR2 + FR3)/3.

a Product of serving score and frequency score.

Serving score: For each dairy product, the frequency (number of times) of consumption was assessed in four frequency categories: never, per day (0–3 times), per week (1–6 times), or per month (1–3 times). Each frequency category was converted into a daily intake.

Frequency score: Scored daily intake based on 300 mg calcium equivalents (i.e. 250 mL for milk, 250 mL for maas, 200 mL for yoghurt, 40 g for hard cheese, and 60 mL for soft cheese).

b Sum of the four product serving scores.

c Paired t-test comparing PSSs/DSSs to food records.

d Pearson (continuous scores).

e Kappa (categorised scores).

f Level of significance for *r*.

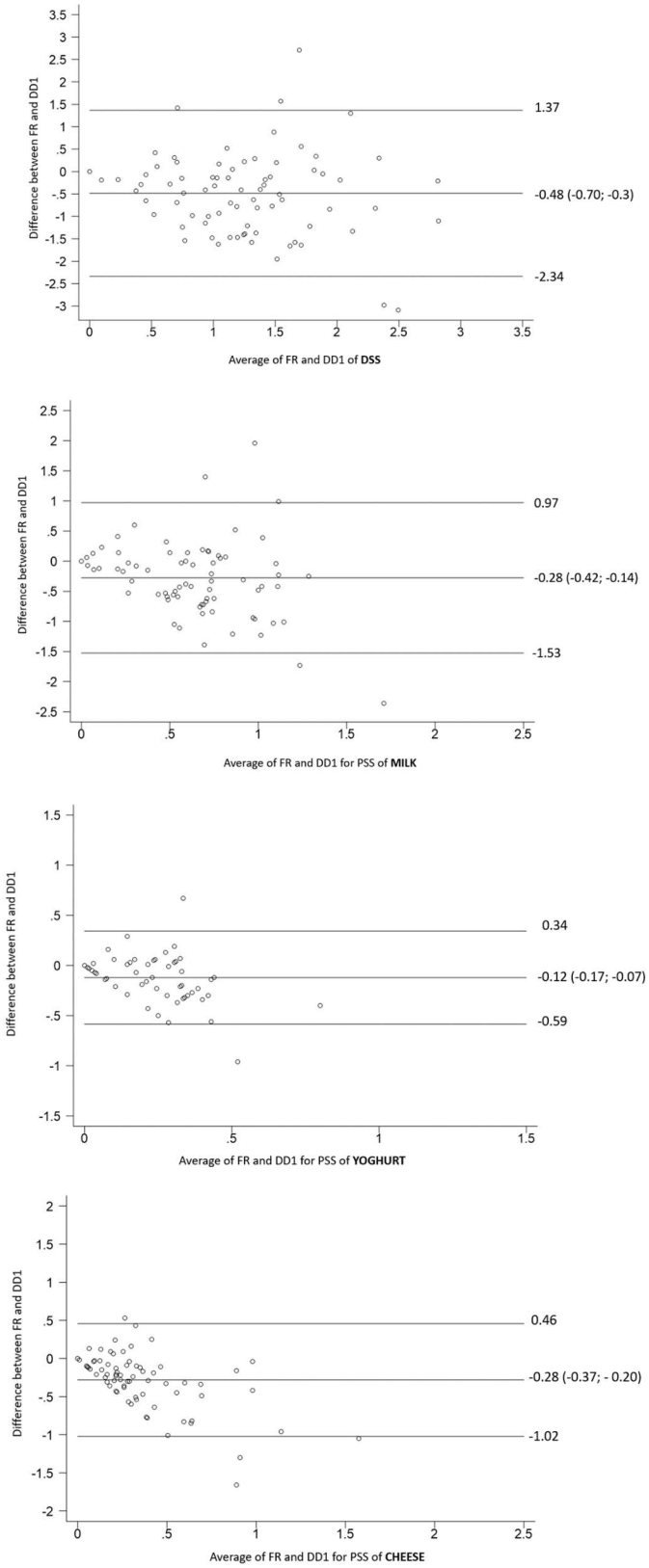

Figure 4.2: Bland–Altman plots for DSSs and PSSs of milk, yoghurt and cheese

Bland–Altman plots for DSSs and PSSs of milk, yoghurt and cheese (n = 79) including mean difference (bias) and limits of agreement (LOA; ± 1.96 SD; 95% CI of the mean difference).

The parameters of the diagnostic accuracy of the DSS of the screener relative to DSS of the food records are shown in Table 4.4. Sensitivity (81.4%) and PPV (93.4%) were higher than specificity (55.6%) and NPV (NPV) (27.8%), respectively. The area under the ROC curve was 0.7. The parameters of the diagnostic accuracy of the DSS of the screener relative to DSS of the food records are also shown in Table 4.4. Sensitivity (81.4%) and positive predictive value (PPV; 93.4%) were higher than specificity (55.6%) and NPV (27.8%), respectively. The area under the ROC curve was 0.7.

Table 4.4: Diagnostic accuracy of the categorised DSS of the Dairy Diary relative to the DSS of the weighed food records (n = 79)

Parameter of diagnostic accuracy	Value (95% CI)
Sensitivity	81.4% (70.3; 89.7)
Specificity	55.6% (21.2; 86.3)
ROC: area under the curve	0.7 (0.51; 0.86)
Positive likelihood ratio (+)	1.83 (0.88; 3.84)
Negative likelihood ratio (−)	0.33 (0.16; 0.72)
Odds ratio	5.5 (4.4; 21.7)
Positive predictive value	93.4% (84.1; 98.2)
Negative predictive value	27.8% (9.7; 53.5)

4.5 Discussion

The aim of the Dairy Diary is to classify individuals into those with and without low dairy intakes. For reliability assessment, mean PSSs and DSSs did not differ significantly between the two screener administrations. Supporting this, correlations were strong for milk, maas, yoghurt and cheese. Similar correlations have been shown elsewhere for milk and cheese (Welten et al., 1995 Goldbohm et al., 2011). McNemar's test for symmetry showed no bias for the DSSs between the two administrations of the Dairy Diary, suggesting that the proportion of individuals who underestimated dairy intake was comparable to the proportion who overestimated their intake in the two administrations. Multiple statistical analyses thus concur with and support test-retest reliability.

For validity assessment, the PSSs of the screener and food records were moderately correlated for milk, yoghurt and cheese, with fair agreement for the categorised DSS. Based on *a priori* LOA of 0.5 servings, the Bland–Altman plot for DSS showed, on group level, acceptable accuracy between DSS for the Dairy Diary and food records, making the Dairy Diary appropriate for research studies where group means are important.

We further quantified the diagnostic ability of the Dairy Diary. Sensitivity referred to the ability of the Dairy Diary to correctly identify participants consuming < 2 servings of dairy per day. Specificity referred to the ability of the Dairy Diary to correctly identify participants consuming ≥ 2 servings of dairy per day. Our results show high sensitivity and low specificity, aligned to sensitivity and specificity values reported for other calcium- and food-based screeners that include dairy products. In such studies, sensitivity values ranged from 56% (Tseng et al., 2021) to 97% (Martela et al., 2019), and specificity values ranged from 12% (Martela et al., 2019) to 87% (Montomoli et al., 2002).

The high sensitivity of the Dairy Diary suggests the screener can correctly identify participants not meeting dairy intake recommendations at the expense of low specificity where the screener is less likely to correctly identify those meeting dairy intake recommendations. It is argued that high sensitivity and high specificity is not feasible (Charney, 2008; Field & Hand, 2015), with a pattern of higher sensitivity and lower specificity (and vice versa) to be expected (Gleason et al., 2010). A balance must be struck, and we reason that the need to correctly identify low dairy intakes (sensitivity) takes precedence over misclassifying those who consume sufficient dairy (specificity) to trigger entry into the nutrition care process for comprehensive dietary assessment (Swan et al., 2017). It would be undesirable to have a high rate of false negatives (i.e. failure to identify those who are at risk of low dairy intakes), given well-established evidence that dairy plays a positive role in managing non-communicable diseases (Thorning et al., 2017; Aljuraiban et al., 2019; Guo et al., 2019; Bhupathi et al., 2020), and helping to meet gap nutrient intakes as a surrogate marker of diets higher in nutritional quality (Weaver, 2014).

Last, we supplemented the diagnostic ability of the Dairy Diary with predictive values, acknowledging that such values are related to population prevalence (Gleason et al., 2010),

and the possibility that dietetics/nutrition students may not be perfectly reflective of the general higher income population of South Africa. Nonetheless, the large proportion of participants with daily dairy intake below 2 servings a day limits this threat. Given that the screener is also intended to create awareness of low dairy intakes, we likewise favoured higher PPVs. In assessing the high positive likelihood ratio (> 1) and low negative likelihood ratios (< 1), results suggest that the Dairy Diary is effective at establishing low dairy intakes, while being effective at ruling out low dairy intakes (i.e. ≤ 2 servings of dairy per day). Furthermore, an odds ratio of 5.5 suggests that the odds of low dairy intake in those consuming < 2 servings of dairy per day are greater than the odds of low dairy intake in those who consume ≥ 2 servings of dairy per day. The area under the ROC of 0.7 suggested that the Dairy Diary had a moderate predictive ability. Previously ROC analyses have been done on a six-item calcium-intake screener (Tseng et al., 2021), yet the area under the curve was not reported.

In general, our results show that the first administration of the Dairy Diary tended to have higher DSSs (and PSSs) than food records. Since the Dairy Diary reflects *usual* dairy intake, whereas weighed food records capture *actual* dairy intake within a seven-day period, perfect agreement may be considered unrealistic. It is, however, also conceivable that the expert predefined serving sizes in the Dairy Diary may partly explain the overestimated portion sizes in the screener. Improvements in performance of FFQs when population-relevant usual portion sizes are included have been reported (Molag et al., 2007; Illner et al; 2012), pointing to the need for locally verified actual dairy portion sizes in the screener.

Strengths of this study include self-administration of the screener and food records (minimising social desirability bias), the two-week time interval between the two administrations of the screener (minimising memory and recall bias), and participant blinding to the outcome of the screening (minimising influence on the second administration). In the absence of a feasible gold standard, three-day weighed food records, consistent with other validity studies were used (Gans et al., 2006; Clover et al., 2007; Sebring et al., 2007; Hacker-Thompson et al., 2009; Goldbohm et al., 2011; Martela et al., 2019).

Food records have an inherently different error structure compared with the FFQ format of the Dairy Diary, minimising systematic error (Gleason et al., 2010). We addressed random

error (linked to day-to-day variation) with repeated (three) and non-consecutive (two weekdays and one weekend day) weighed food records to mimic usual intake, assuming dairy intake was not seasonal. Systematic error was managed with standardised instructions to participants on how to record food intake. We further elected to not exclude non-dairy consuming participants as outliers, which may have led to inflated estimates of the reliability and validity of the Dairy Diary, thereby weakening the diagnostic accuracy of this study.

In terms of the screener, recommendations include the use of the ROC analysis to optimise cut-off values to improve sensitivity and specificity values. In our study, it was not attempted as this may differ depending on prevalence rates of low dairy intake within the population. The Dairy Diary was developed for high-income South African adults, yet the inclusion of maas, a traditional fermented milk may have been less relevant to the young sample population (university students) included in our study. Reconsidering the role of maas in the screener may be necessary, or, alternatively, we recommend redefining the target market.

We acknowledge that volunteer participants of dietetics/nutrition students may naturally be more food aware and healthier than the general population (Clover et al., 2007), leading to a potential selection bias which could limit the generalisability of this study. While the assumption of 60% of the population meeting dairy intake recommendations was not met, our sample of 79 remained aligned to the recommended 50–100 participants in validation studies (Cade et al., 2002). The assessment of the validity of a dietary screening tool is ongoing and further studies exploring the applicability of the Dairy Diary in other population groups (including males, participants without a nutrition background, younger children, and older adults) will be valuable.

4.6 Conclusion

The Dairy Diary has good test-retest reliability and fair comparative validity to screen for dairy intake in the study population of higher income South African adults.

4.7 Acknowledgement

The development of the Dairy Diary was supported by the Consumer Education Project (CEP) of Milk South Africa. The Technical Advisory Committee of the CEP is hereby acknowledged. The Nestlé Nutrition Institute of Africa is acknowledged as part funders of this study.

4.8 Conflict of Interest

Prof. FAM Wenhold and Dr. Z White are members of the Technical Advisory Committee of the CEP of Milk SA. The working group who developed the Dairy Diary was blinded to the algorithm used to calculate the DSS.

4.9 Availability of Data and Materials

The data set used and analysed during the current study is available from the University of Pretoria on reasonable request.

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5 CHAPTER 5: GENERAL DISCUSSION, RECOMMENDATIONS AND CONCLUSION

In these modern times, ease of access to health and nutrition information via mobile phones has allowed for the emergence of innovative tools for dietary screening.[1,2] The nutrition professional stands at crossroads in the advancement of technology-based methods of dietary screening, while appreciating and acknowledging that the performance of these tools needs to be validated.[3]

Simultaneously, dairy intake in South Africa is low.[4] Screening for dairy intake could initiate behaviour change by raising awareness of consumption not meeting recommendations, more so if linked to nutrition education on the importance of dairy in the diet. A dairy intake screener may indirectly create awareness of low dairy intakes and the importance thereof, thereby initiating, motivating, and driving behaviour change. This, in turn, may support and drive nutrition education to improve dairy intake in South Africa.

As such, the Dairy Diary[5] was commissioned for development by the CEP, an initiative of Milk SA[6] to protect and promote the dairy industry. Funded by government and industry, the CEP is committed to consumer education on the importance of dairy in the diet. Should the Dairy Diary contribute to the quick assessment of dairy intake, this can alert the consumer to low intakes with the purposeful inclusion of preliminary targeted guidance to educate on increasing dairy intake. In turn, this informs the consumer of the health and nutritional advantages of dairy products, which further supports the responsibility of the CEP to create awareness of dairy intake.

This research study aimed to evaluate the usability (user-friendliness) and validity (test-retest reliability and comparative validity) of the Dairy Diary in South African adults in two sub-studies. The usability sub-study included the evaluation of the user-friendliness of the Dairy Diary using uMARS in an online cross-sectional survey by respondents comprising consumers and nutrition professionals. In a diagnostic accuracy study, the validity sub-study included a purposefully recruited sample of undergraduate dietetics/nutrition students from three South African universities who completed three days of weighed food records (reference standard) within a seven-day period (comparative validity), followed by two administrations of the Dairy Diary (index test) (reliability), two weeks apart.

In addition to the discussions presented in the manuscripts of Chapter 3 and Chapter 4, respectively, a general discussion on each sub-study follows. Table 5.1 summarises the key results of each sub-study.

Table 5.1: Summary of results in the usability and validity sub-studies

Usability sub-study	Validity sub-study
For consumers, the Dairy Diary: ▪ Was quick and easy to use. ▪ Met the minimum mean acceptability score for the objective quality, app subjective quality, and app-specific score. ▪ Met the minimum mean acceptability score for the additional question on e-portions. ▪ Scored highest for aesthetics (followed by information and functionality). ▪ Scored lowest score for engagement.	Among dietetics/nutrition students, the Dairy Diary: ▪ Was test-retest reliable. ▪ Had moderate potential to be a comparatively valid tool to screen for dairy intake of groups. ▪ Was highly sensitive at the expense of specificity.

5.1 General Discussion on the Development of the Dairy Diary

The development of the Dairy Diary was initiated and funded by the CEP of Milk SA[6] in November 2017, informed by the South African national food-based dietary guidelines on dairy to "Have milk, maas and yoghurt everyday". The CEP of Milk SA defines the reference serving size of dairy as an amount containing 300 mg of calcium, which directed the portion sizes used in the screener.

This project was initiated prior to the candidate's enrolment for post-graduate studies. As such, the development of the screener did not feature within the ethics proposal to the REC of the Faculty of Health Sciences (October 2018), and the development of the Dairy Diary was reported for descriptive purposes only and was not addressed as a standalone objective in this dissertation.

According to Willet et al.[7] the selection of food types and portion sizes, based on the food consumption data of the population to be studied, provides the backbone of the development

of a FFQ. The researcher did not use the Willet approach for several reasons. First, the Willet steps refer to the development of a comprehensive FFQ, whereas the Dairy Diary is a screener with a FFQ format. Second, the lack of quantitative and updated national dietary intake data on dairy intake in South Africa did not provide food consumption data, and more specifically dairy consumption data, for the development of the Dairy Diary. This was further justified by the disaggregation of the study population by LSM, as per the inclusion criteria and informed by the high cost of dairy products and technology in the country. Results from the National Dietary Intake Study of 2022 will present the opportunity to use actual, current consumption data for future developments of food-specific dietary screeners in South Africa.

5.2 General Discussion on the Usability Sub-study

For the usability sub-study, this research included a report on the development of the Dairy Diary using the five-step best practice guidelines recommended by the ILSI Europe Dietary Intake and Exposure Task Force for reporting on technologically based dietary assessment tools.[2] Results of the usability sub-study showed that the Dairy Diary, as evaluated by uMARS,[8] was quick and easy to use. The screener met the minimum mean acceptability score of ≥ 3.0[9] for the app quality score (objective), app quality score (subjective), and app-specific score. It further met the minimum mean acceptability score of ≥ 3.0 for the additional question on e-portions. The Dairy Diary has the highest score for aesthetics (followed by information and functionality), with engagement scored lowest.

This research has shown that the Dairy Diary is a user-friendly, unique, and novel technology-based tool. This may provide researchers and nutrition professionals with a cost-effective, convenient, and practical dietary screening tool for evaluating and encouraging dairy intake in South Africa. It further allows for initiatives such as the CEP of Milk SA to promote and protect dairy intake by creating awareness of low intakes among South African consumers. Plant-based/non-dairy alternatives have proliferated the market in recent years with reports of 61% increase in plant-based alternatives since 2013.[10] The associated declines in dairy intake linked to this transition may have further implications for the dairy industry, motivating for dairy advocacy and protection by initiatives such as the CEP.

Usability studies on technology-based dietary assessment methods in Australia[11] and Ireland[12,13] reported high levels of respondent acceptance towards using mobile apps for dietary assessment, as confirmed in the usability sub-study of this research. Of note, levels of acceptance and usability tend to be lower for respondents with lower educational levels.[1,14] Aligned to the target group identified by the CEP, this sub-study included higher income groups. The respondents potentially have higher education levels, which may have inflated the levels of acceptance of the Dairy Diary.

Dairy products are expensive in South Africa, which coupled with high mobile data costs[15] justified the inclusion of high-income groups. However, it is recommended that the usability sub-study be repeated in lower income groups. A study in China showed that, compared with medium- and high-income families, intake of dairy products in low-income groups is more sensitive to income and price fluctuations.[16] Similarly, Romanian consumers reported price as an influencing factor in dairy purchase.[17] If dairy products are expensive, those with low dairy intakes may thus be from lower income groups, where screening for dairy intake is important.

Last, usability studies on web-based FFQs have shown that technology versions are generally favoured over traditional versions.[2,18] The objectives of the sub-study of this research did not include the appraisal of respondent preference of the web-based mobile app format of the Dairy Diary in comparison to a print (traditional) version.

Though technology-based screening tools continue to gain popularity, the limitations thereof are recognised. Such dietary screeners may not be applicable to groups unfamiliar with modern technologies, such as the elderly. Accordingly, there may be considerations related to selection bias of the consumer respondents in this research.[19,20] The relatively young sample of the usability sub-study may have further influenced selection bias, accounting for the favourable assessment of user-friendliness of the Dairy Diary.

Another limitation is that the use of dietary screeners may be influenced by reactivity bias [12,21] and social desirability response bias.[22] Social desirability refers to a respondent's tendency to present responses in research in a way that is perceived to be more socially acceptable.[23] This is a potential risk in survey-based research, like this sub-study, where self-report is required.[24] In general, respondents in this sub-study self-reported as being "very healthy". In addition,

some (18%) were nutrition professionals. It can be argued that these characteristics of the sample naturally introduced reactivity and social desirability response biases to the study. That said, though this type of bias is often viewed as a confounding factor in survey-based research, other evidence suggests it plays only a minor role.[25]

A consideration regarding technical limitations (i.e. poor internet connection) is warranted prior to technology-based dietary screeners becoming routine practice. In South Africa, 72% of the population have access to the internet,[26] with internet and fibre-to-the-home/building internet subscriptions increasing.[27] Consequently, it is deemed that the format of the Dairy Diary as a web-based mobile app remains appropriate for use in a population of relatively high internet penetration in South Africa.

Last, the practical implications of utilising mobile apps for public health initiatives must be mentioned. This may include enhanced accessibility to health information, improved user engagement, and the potential for real-time data collection and analysis. A systematic review on mobile app-based health promotion reported better health outcomes for mobile users compared to non-users.[28]

5.3 General Discussion on the Validity Sub-study

"There will always be error in dietary assessment. The challenge is to understand, estimate and make use of the error structure during analysis".

This statement by Beaton et al.[29] emphasises the core of this research, highlighting the role of validity studies on novel dietary screening tools in describing the type and magnitude of inherent errors when measuring diet. For the validity sub-study, results showed that the Dairy Diary was test-retest reliable to screen for dairy intake, with moderate comparative validity to screen for dairy intake. The screener had high sensitivity, yet good specificity could not be achieved simultaneously.

When conducting validation studies for dietary assessment, Kirkpatrick et al.[30] recommend the avoidance of treating validity and/or reliability as a dichotomous finding. There is further no consensus on the most appropriate statistical methods to evaluate the validity of a dietary

screener.[31] As such, this research used a complement of statistical tests to provide comprehensive and congruent insight into validity. In the validity sub-study, t-tests, Pearson correlations (*r*), Kappa (κ), Bland–Altman, McNemar's test for symmetry, and diagnostic accuracy (Se, Sp, PPV, NPV, ROC) were determined to assess for test-retest reliability and comparative validity. Table 5.2 summarises the statistical tests used to inform the concluding remarks on assessment of reliability and validity of the Dairy Diary.

With reference to predictive values, PPV and NPV are suggested as statistical tests when screening is likely to be conducted by a non-nutrition professional.[32] High PPV and low NPV of the Dairy Diary was reported in this research. Having included these statistical tests in the validity sub-study affirms that the Dairy Diary study may be conducted by other trained professionals. Furthermore, on group level, the Bland–Altman plot for DSS showed acceptable accuracy between DSS for the Dairy Diary and food records. Taken together, this supports that the Dairy Diary is appropriate for use as a dairy intake screener in research studies where group values are important.

It is argued that predictive values need not always be high[33] predictive values are dependent on the population being tested and related to disease prevalence.[34] In this research, consistent with population-based data on dairy intake in South Africa,[4] dairy intakes lower than the recommended ≥ 2 servings per day for both the Dairy Diary and weighed food records were reported. The observed pattern of a higher PPV than NPV implies that false positives are minimised, which is desirable when the risk of poor dairy intake is not identified and entry into the nutrition care process is delayed. In the context of the positive role that dairy plays in health, a dairy intake screener that delays the identification of low dairy intake is more of a concern than a screener that overidentifies high dairy intake. These predictive values would, however, change should the Dairy Diary be validated in a different population group, such as one with a higher dairy intake.

Table 5.2: Summary of statistical tests and their outcomes for reliability and validity assessment

Variables		Statistical tests and their outcomes									
		t-test	Correlations (*r*)[a]	Kappa (κ)[b]	Bland–Altman plot[c]	McNemar's test for symmetry	Diagnostic accuracy				
							Se (%)	Sp (%)	PPV (%)	NPV (%)	ROC[d]
Reliability	**PSSs: continuous**	Did not differ significantly. (all P > 0.05)	Milk: Strong (*r* = 0.69) Maas: Strong (*r* = 0.72) Yoghurt: Strong (*r* = 0.71) Cheese: Strong (*r* = 0.74)								
	DSS: continuous	Did not differ significantly. (P > 0.05)	DSS: Strong (*r* = 0.68)								
	DSS: categorised			DSS: Moderate (κ = 0.45)		Non-agreeing responses symmetric (P = 0.334)					
Validity	**PSSs: continuous**	Did not differ significantly. (all P > 0.05)	Milk: Moderate (*r* = 0.30) Maas: n/a Yoghurt: Moderate (*r* = 0.38) Cheese: Moderate (*r* = 0.38)								
	DSS: continuous	Did not differ significantly (P > 0.05)	DSS: Moderate (*r* = 0.30)		Acceptable agreement, considerable imprecision						
	DSS: categorised			DSS: Fair (κ = 0.31)			81.4	55.6	93.4	27.8	0.7

Se: Sensitivity; Sp: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; ROC: Receiver operating characteristic

[a] Pearson: Poor (*r* < 0.2), moderate (*r* = 0.2–0.6) and strong (*r* > 0.6)[35,36]

[b] Strength of agreement for Kappa can be described as poor (κ < 0), slight (κ = 0.01–0.2), fair (κ = 0.21–0.40), moderate (k = 0.41–0.60), strong (κ = 0.61–0.80), and almost perfect (κ = 0.81–1.0).[37]

[c] Clinically relevant *a priori* acceptable level of error (Hanneman, 2008) was defined as 0.5 dairy servings (i.e. 75% of the recommended dairy intake of ≥ 2 servings per day.

[d] For ROC, the area under the curve was 1.0 for a perfect test and 0.5 for a poor outcome.[39]

In nutrition research, the assessment of usual or true dietary intake will always be a challenging yet necessary undertaking, driving continued discussion and debate on the most accurate method for assessing dietary intake.[40] Since no gold standard exists, a measure of validity can only be comparative and assessed by another method deemed to be superior.[41] Three-day (non-consecutive) weighed food records were used as a reference standard in the validity sub-study – a dietary assessment method commonly used in validation studies.[41] Food records have a great degree of demonstrated validity, even if not an exact measure of usual dietary intake.[34] Though the Dairy Diary (with an FFQ format) and food records are both inherently limited by some degree of inaccuracy, the two methods are independent of each other, managing correlation of errors.[34] However, the reliance on subjective participant reporting is a major limitation of both food records and FFQ. It is associated with random and systematic errors such as underreporting of dietary intake, inaccuracies in portion size estimation, with daily variation of intake and the failure to report on usual intake. The risk of participants altering dietary intake related to the burden of recording complex foods should also not be overlooked.[41,42]

To address these challenges, the use of other reference standards, independent of random and systematic errors, should be considered. Such limitations can be overcome with the use of biomarkers as a reference standard to objectively assess food consumption with independence and without the bias of (subjective) self-reported dietary intake.[40,43] Biomarkers can be a nutrient, food component or metabolite accessible from blood (plasma, serum, or blood cells), excretion products (faeces or urine), or other easily obtainable specimens (skin, saliva, or hair), serving as an objective measure to represent dietary or nutrient intake. This reference standard can help determine intakes of foods and food groups in conjunction with and to complement self-reported dietary screeners.[44] Biomarkers have the advantage of not relying on participant self-reporting, and thus may overcome the inherent challenges of respondent bias in dietary screening.[43]

For the validity sub-study of this research, the use of a biomarker as an additional complementary reference standard is acknowledged. That said, the use of biomarkers as a reference standard would have been limited as, to our knowledge, there are no biomarkers for dairy as a food group. Rather, biomarkers for dairy intake are limited to assessing dairy fat,

using certain short chain fatty acids and amino acids. Examples of biomarkers for dairy fat include odd-chain saturated fatty acids such as pentadecanoic acid (C15:0) and heptadecanoic acid (17:0),[45,46] serum short chain fatty acids,[47] glutamine,[48] proline,[48] aspartic acid,[48] and urinary citrate.[49] As such, in a dairy intake screener that includes full cream, low and non-fat dairy products as a food items, such as the Dairy Diary, careful consideration on the choice of biomarker is important. For example, C15:0 and C17:0 are not useful biomarkers in assessing for low fat dairy products and perform poorly for total dairy intake.[50] A proposed solution could be to use a combination of biomarkers to increase precision. For example, the sum of C15:0, C17:0, and/or trans-palmitoleic acid (t16:1n-7) has been used as a biomarker for dairy fat.[451] A biomarker for calcium intake could also be considered. Given that non-dairy food sources of calcium may also contribute to dietary calcium intake, again, this would limit the use of a biomarker for calcium.

Thus, the choice of biomarker as a reference standard requires careful consideration. Ideally, biomarkers should be highly specific to one food item or food group (i.e. dairy), have a dose- and time-dependent response after intake, must not be detected in a sample when the food item is not ingested, and must not be susceptible to interindividual variation. Though biomarkers may present independent errors compared with traditional methods, biomarkers do not replace the traditional method (i.e. food record) for assessing dietary intake. Rather, a biomarker is used as an additional measure. For this reason, a triads method is suggested, which includes two traditional dietary assessment methods along with biomarkers in the validation of an index test.[44]

Last, the use of a biomarker in this study would have been challenged by budget and logistics related to the large geographical distance between participants in the validity sub-study across three South African provinces. For these reasons, biological specimens were not considered to serve as biomarkers as the reference standard for this study.

5.4 Conclusion

The Dairy Diary is a dietary screening tool that employs technology in the assessment, immediately providing a result and a referral to the user, while showing to be user-friendly and test-retest reliable. Even though individual-level error must be expected, the Dairy Diary

has the potential to be comparatively valid to screen for dairy intake in groups, as in research studies.

A dairy intake screener that is user-friendly and valid may help support and promote current low dairy intakes in South Africa by alerting the consumer to poor intakes, thereby providing a platform to emphasise dairy-based nutrition education. Further research could address validating the Dairy Diary in other groups, such as in young children, the elderly and lower income groups, which may help create dairy intake awareness across larger segments of South Africa.

With the ever-increasing usage of smartphones and mobile apps, coupled with continued internet penetration across the country, a technology-based dairy intake screener will serve as an original contribution to the field of nutrition and dietetics in South Africa.

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ANNEXURE A: ETHICAL APPROVAL AND LETTERS OF CONSENT

Ethical Approval: University of Pretoria 2019

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

31 May 2019

Approval Certificate
New Application

Ethics Reference No.: 705/2018
Title: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Dear Mrs MC Piderit

The **New Application** as supported by documents received between 2019-04-09 and 2019-05-29 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-05-29.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-05-31.
- Please remember to use your protocol number (705/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Ethical Approval: University of Pretoria 2020

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

11 March 2020

Approval Certificate
Annual Renewal

Ethics Reference No.: 705/2018
Title: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Dear Mrs MC Piderit

The **Annual Renewal** as supported by documents received between 2020-02-27 and 2020-03-11 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2020-03-11.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2021-03-11.
- Please remember to use your protocol number (705/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

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Ethical Approval: University of Pretoria 2021

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

22 January 2021

Approval Certificate
Annual Renewal

Ethics Reference No.: 705/2018
Title: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Dear Mrs MC Piderit

The **Annual Renewal** as supported by documents received between 2021-01-04 and 2021-01-20 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2021-01-20 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2022-01-22.
- Please remember to use your protocol number (705/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Ethical Approval: University of Pretoria 2022

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567. Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023.

Faculty of Health Sciences **Research Ethics Committee**

14 April 2022

Approval Certificate
Annual Renewal

Dear Mrs MC Piderit,

Ethics Reference No.: 705/2018 – Line 3
Title: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

The **Annual Renewal** as supported by documents received between 2022-03-16 and 2022-04-13 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2022-04-13 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2023-04-14.
- Please remember to use your protocol number (705/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Ethical Approval: University of Pretoria 2023

UNIVERSITEIT VAN PRETORIA
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Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023.

Faculty of Health Sciences **Research Ethics Committee**

23 March 2023

Approval Certificate
Annual Renewal

Dear Mrs MC Piderit,

Ethics Reference No.: 705/2018 – Line 4
Title: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

The **Annual Renewal** as supported by documents received between 2023-02-20 and 2023-03-15 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-03-15 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2024-03-23.
- Please remember to use your protocol number (705/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Professor C Kotzé
MBChB, DMH, MMed(Psych), FCPsych, Phd
***Acting Chairperson**: Faculty of Health Sciences Research Ethics Committee*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Letter of Approval: Deputy Dean of Teaching And Learning

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

2018 – 10 - 18

The Chair
Research Ethics Committee
Faculty of Health Sciences
University of Pretoria

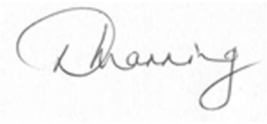
Ethical approval for student research project

This serves to confirm that I am supportive of Monique Cruz Piderit s28020945, a PhD Dietetic student in DEK990, who has applied for ethical approval for her project entitled:

USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

I have no objection to her requesting the third year dietetic and nutrition students (BDietetics and BSc Nutrition) enrolled in NTA 313/314 to participate in the study by completing an anonymous online questionnaire and submitting 3-day weighed food records.

Kind regards,



Prof D Manning
Deputy Dean: Teaching and Learning

Ethical Approval: North-West University 2021

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: +2718 299-1111/2222
Web: http://www.nwu.ac.za

Research Data Gatekeeper Committee

NWU RDGC PERMISSION GRANTED / DENIED LETTER

Based on the documentation provided by the researcher specified below, on 17/01/2020 the NWU Research Data Gatekeeper Committee (NWU-RDGC) hereby grants permission for the specific project (as indicated below) to be conducted at the North-West University (NWU):

Project title: Usability and validity of a dairy intake screener as a web-based mobile application for South African adults.

Project leader: Prof F.A.M Wenhold
Researcher/Project Team: M Piderit

Ethics reference no: 705/2018
NWU RDGC reference no: NWU-GK-2019-069

Specific Conditions:
The researcher is to appoint an independent recruiter will brief students on the nature of the study to provide informed consent to access photocopies of the food records that were submitted for the module assessment.

Approval date: 17/01/2020 **Expiry date: 16/01/2021**

General Conditions of Approval:

- The NWU-RDGC will not take the responsibility to recruit research participants or to gather data on behalf of the researcher. This committee can therefore not guarantee the participation of our relevant stakeholders.
- Any changes to the research protocol within the permission period (for a maximum of 1 year) must be communicated to the NWU-RDGC. Failure to do so will lead to withdrawal of the permission.
- The NWU-RDGC should be provided with a report or document in which the results of said project are disseminated.

Please note that under no circumstances will any personal information of possible research subjects be provided to the researcher by the NWU RDGC. The NWU complies with the Promotion of Access to Information Act 2 of 2000 (PAIA) as well as the Protection of Personal Information Act 4 of 2013 (POPI). For an application to access such information please contact Ms Annamarie De Kock (018 285 2771) for the relevant enquiry form or more information on how the NWU complies with PAIA and POPI.

The NWU RDGC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the NWU RDGC for any further enquiries or requests for assistance

Yours sincerely

Prof Marlene Verhoef
Chairperson NWU Research Data Gatekeeper Committee

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 086 016 9698
Web: http://www.nwu.ac.za/

North-West University Health Research Ethics Committee (NWU-HREC)

Tel: 018 299-1205
Email: Ethics-HRECApply@nwu.ac.za (for human studies)

2 June 2021

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Health Research Ethics Committee (NWU-HREC) on 02/06/2021, the NWU-HREC hereby approves your study as indicated below. This implies that the NWU-HREC grants its permission that, provided the general conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Usability and Validity of a Dairy Intake Screener as a Web-Based Mobile Application for South African Adults
Principal Investigator/Study Supervisor/Researcher: FAM Wenhold
Student: MC Piderit (external student)

Ethics number:

N	W	U	-	0	0	4	6	1	-	1	9	-	A	1
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: External application
Commencement date: 02/05/2021

Risk: Minimal

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-HREC:*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for active monitoring.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-HREC reserves the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected;*
    - *it becomes apparent that any relevant information was withheld from the NWU-HREC or that information has been false or misrepresented;*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

- *NWU-HREC can be contacted for further information via Ethics-HRECApply@nwu.ac.za or 018 299 1206*

Special conditions of the research approval due to the COVID-19 pandemic:

Please note: Due to the nature of the study i.e. (collection of data from student practicals within a university environment), this study will be able to proceed during the current alert level, following receipt of the approval letter. No additional COVID-19 restrictions have been placed on the study except that the researcher must ensure that before proceeding with the study that all research team members have reviewed the North-West University COVID-19 Occupational Health and Safety Standard Operating Procedure.

The NWU-HREC would like to remain at your service and wishes you well with your study. Please do not hesitate to contact the NWU-HREC for any further enquiries or requests for assistance.

Yours sincerely,

Digitally signed by
Prof Petra Bester
Date: 2021.06.02
14:20:43 +02'00'

Chairperson NWU-HREC

Ethical Approval: University of the Free State 2018

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Me Monique Piderit
PhD Dietetic student
Faculty of Health Sciences
University of Pretoria

08 December 2018

Dear Monique

Letter of approval

This letter serves to confirm that the Department of Nutrition and Dietetics at the University of the Free State is supportive of you including the third and fourth year students in this department in your study titled:

USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

We have no objection to the students participating in the study by completing an anonymous online questionnaire and submitting 3-day weighed food records.

Kind regards,

Prof Corinna Walsh

Ethical Approval: Consumer Education Project of Milk South Africa 2018

sampro

South African Milk Processors' Organisation
The voluntary organisation of milk processors for the promotion of the development of the secondary dairy industry to the benefit of the dairy industry, the consumer and the South African society

PhD Study of Ms Monique Piderit

4 July 2018

To whom it may concern

The Consumer Education Project of Milk South Africa acknowledges that the Dairy Diary online tool will be part of the PhD study of Monique Piderit. The study will test the relevance of the Dairy Diary among consumers in terms of its usability and validity.

Monique Piderit was part of the task team of the Consumer Education Project of Milk SA that developed the Dairy Diary online tool, for use by the Project to create awareness of dairy among consumers.

The Dairy Diary is hosted on the www.dairygivesyouago.co.za website of the Consumer Education Project of Milk SA.

The Consumer Education Project of Milk SA, supports the study.

Yours sincerely

Mr Alwyn Kraamwinkel
Chair of the Management Committee of the CEP

Mrs Christine Leighton
Project coordinator of the CEP

Old Farm Office Park,
861 Old Farm Road,
Faerie Glen, Pretoria
PO Box 1852
Silverton, 0127

sampro

Phone +27 (12) 991 4264
Fax +27 (86) 504 9460
E-mail
Website http://www.sampro.co.za

Letter of Clearance: Biostatistician

Date: 8 / 8 /2018

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student(s),

with the Name(s) Ms Monique Pieters

Studying at the University of Pretoria

discussed the Project with the title Development, usability & validity of a dairy intake screener as a web-based mobile application for South African adults.

with me.

I hereby confirm that I am aware of the project and also undertake to assist with the Statistical analysis of the data generated from the project.

The analytical tool that will be used will be 95% CI to estimate MAPE over for usability (N>30), measures of agreement to assess reliability and validity of a Dairy Diet Intake Screening tool compared to food records as reference.
to achieve the objective(s) of the study.

Name: PJ Becker Date 8/8/18

Signature _____ Tel: 012-319-2203

Research Office, Faculty of Health Sciences, University of Pretoria

BIOSTATISTICS
Faculty of Health Sciences
Research Office
2018 -08- 08
UNIVERSITY OF PRETORIA

ANNEXURE B: CHECKLIST VALIDATION STUDIES FOR DIETARY ASSESSMENT

(Adapted from Kirkpatrick et al., 2019)

Topic	Description
Title and abstract	▪ Describe study design and purpose. ▪ Include the dietary components of interest and over what time frame. ▪ Explain dietary assessment measure to be validated. ▪ Provide an informed and balanced summary of what was done and found. ▪ Avoid summary statements that do not reflect the totality of the findings. ▪ Avoid treating validity and/or reliability as dichotomous.
Introduction	
Background and rationale	▪ Provide scientific background and rationale**.** ▪ Give context of current evidence research on dietary assessment methods to justify focus of study**.**
Objectives	▪ Identify objectives, hypotheses, and aim of the study within the specified population and setting.
Methods	
Study design	▪ Present key elements of the study design**.**
Measure	▪ Describe measure to be validated (i.e. development, adaptation, format, method, location of administration, characteristics, e.g. food composition database(s), dietary supplementation). ▪ Describe intended use of the measure (e.g. to capture occurrence of consumption (or not), to rank intake in group, and to estimate absolute intake). ▪ Describe dietary components (e.g. foods, food groups, nutrients, and patterns). ▪ Indicate time frame of interest**.**
Settings	▪ Describe setting, locations, relevant dates (e.g. recruitment period and data collection period). ▪ Describe whether participant dietary intake may be influenced**.**
Participants	▪ Indicate eligibility criteria. ▪ Indicate sources and methods of participants selection. ▪ Indicate and justify sample size. ▪ Describe representativeness of sample within target population**.** ▪ Indicate response rates.

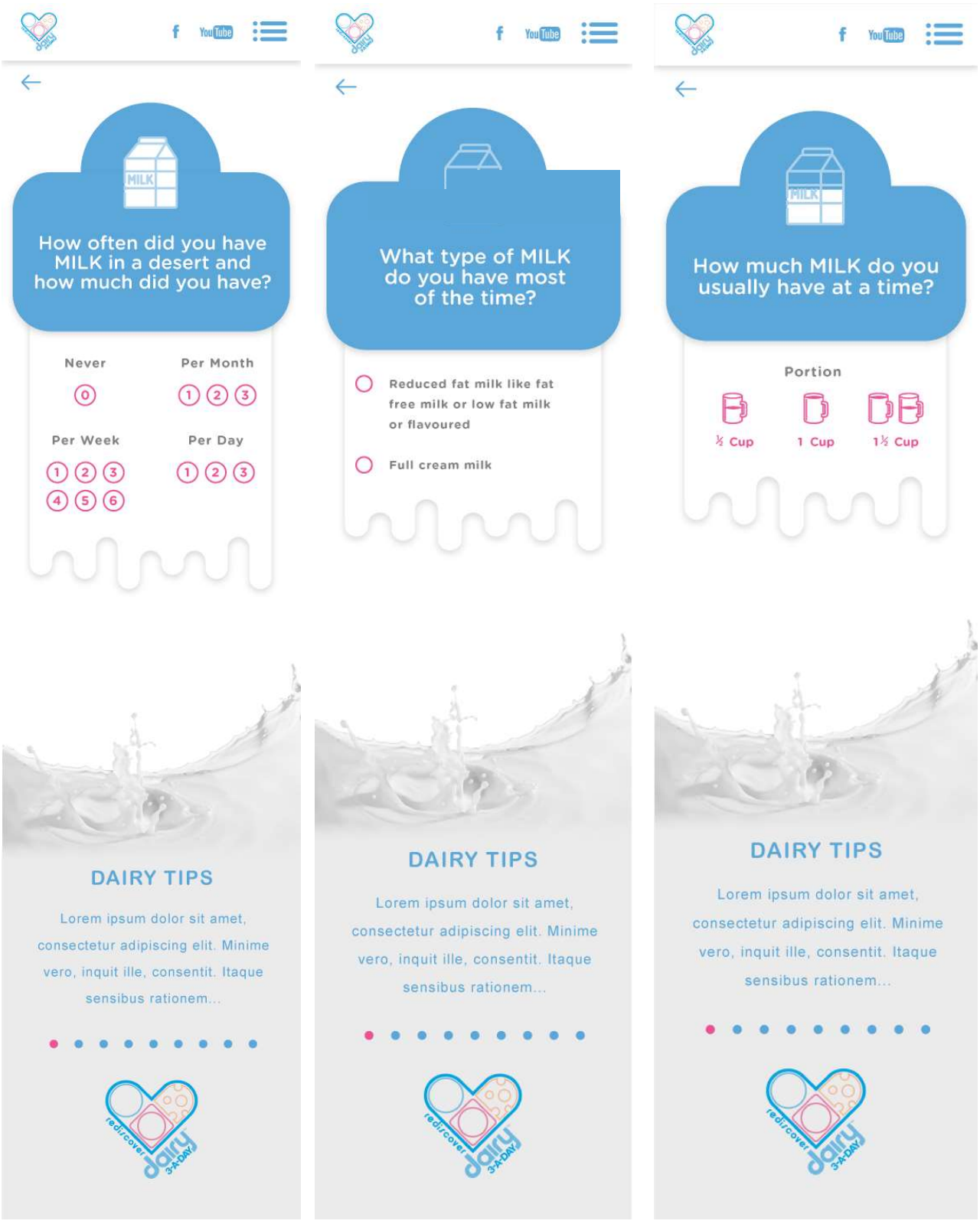
Topic	Description
Procedures	▪ Determine face and content validity: Is the tool well-constructed and grounded in an understanding of the underlying phenomenon of interest? ▪ Provide detailed presentation of the procedures employed to gather feedback to assess whether items reflect the construct of interest (e.g. reviews of relevant literature, survey of lay persons and/or relevant experts). ▪ Address approaches employed to ensure the items included are comprehensive and reflect the most consumed sources of the dietary components of interest. Indicate portion sizes. ▪ Address construct validity: Does the measure perform in a manner consistent with the theory underlying its construction? ▪ Describe the methods used to examine whether the measure assesses the intended construct. ▪ Include a detailed description of statistical procedures used. ▪ Address criterion/relative validity: Is the measure accurate within specified performance standards? ▪ Describe reference measure(s) for validation and justify the use of reference measure(s) in terms of the dietary components and time frame of interest. ▪ Include potential biases. Avoid labelling the reference standard a gold standard. ▪ Address whether the reference measure(s) and the measure undergoing validation assess intake over the same period of time. Describe considerations regarding number and timing of administration(s) of both the measure to be evaluated and the reference measure(s). ▪ Describe and justify choice of statistical analyses. ▪ Address reliability: Does the measure produce data that are precise and dependable? ▪ Describe aspects of reliability of interest e.g. precision (test-retest reliability with relevant period of time over which reliability is of interest) or interrater reliability. ▪ Indicate if changes in dietary intake could be i.e. confounding factors and how this was addressed. ▪ Explicitly describe the statistical tests used. Use multiple tests as appropriate. ▪ Is the measure responsive to change?

Topic	Description
	▪ Describe procedures used to assess responsiveness to meaningful change over time and to assess the smallest detectable change for given dietary components. ▪ Comment on issues related to statistical power related to responsiveness. ▪ Does the measure produce data that are equivalent or comparable across populations? ▪ Discuss approach to comparability in terms of adapting measures for different contexts or identifying particular variables captured using different measures but that can be theoretically harmonised.
Results	
Participants	▪ Indicate participant numbers at each phase of the study. ▪ Indicate reasons for non-participation at each stage. Consider a flow diagram. ▪ Report results of each procedure implemented for each dietary construct of interest.
Descriptive data	▪ Describe participants (e.g. demographic data). ▪ Provide dietary intake data, e.g. low or high values, avoidance of certain foods.
Discussion	
Key results	▪ Provide statistical analyses to objectively summarise key findings with reference to the (sub)study aim and objectives**.** ▪ Discuss degree of validity, reliability, sensitivity to change, and/or equivalence of the evaluated measure as appropriate to the study, rather than referring to these properties as present or absent. When comparing error-prone measures to one another, consider the contribution of correlated error to measures of association. ▪ Avoid overstating the level of validity or reliability based on the available data**.**
Limitations	▪ Describe study limitations that may affect conclusions (e.g. reference measures in studies of validity or recruitment methods, such as renumerated participants)**.**
Interpretation	▪ Limit interpretations about validity, reliability, responsiveness, and/or equivalence of the evaluated measure to the specific populations and contexts evaluated, as well as the particular objectives (e.g. interpretations of an evaluation of validity should be limited to validity and not reliability).

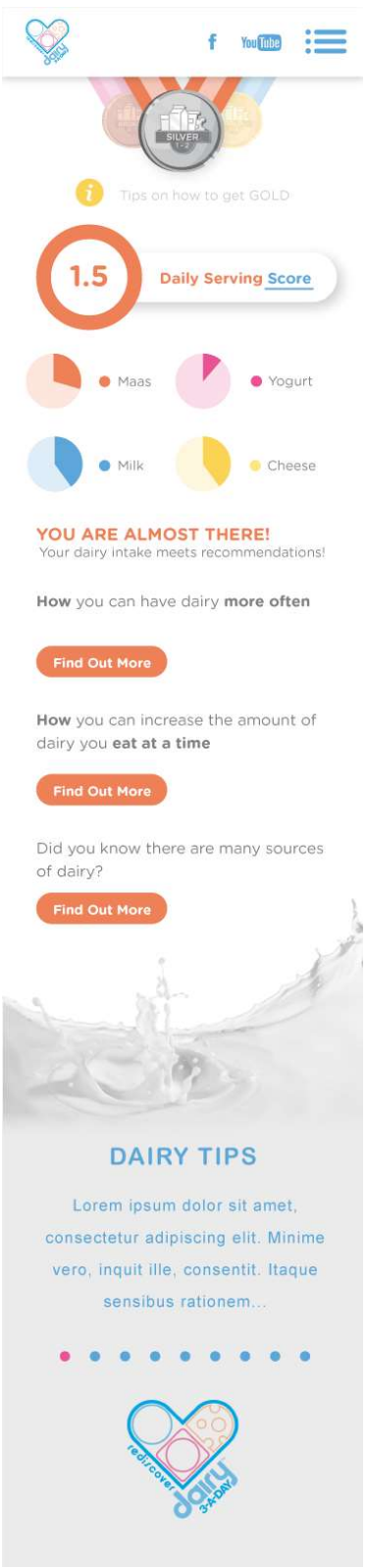
Topic	Description
	▪ Base interpretations on total evidence, including all tests and comparisons conducted, as well as results from similar studies. Place the findings in the context of other literature.
Generalisability	▪ Describe potential appropriate and inappropriate uses of the measure given the study design and findings**.** ▪ Describe features of the measure that may influence the design of studies proposing to use it (e.g. sample size calculations to account for loss of power due to biased measurement of dietary intake).
Other information	
Funding	▪ Indicate funding and role of the funders in the present validation study as well as prior studies on which the present validation study is based, if applicable.
Ethics	▪ Describe the procedures for informed consent and study approval from the relevant ethics committee.

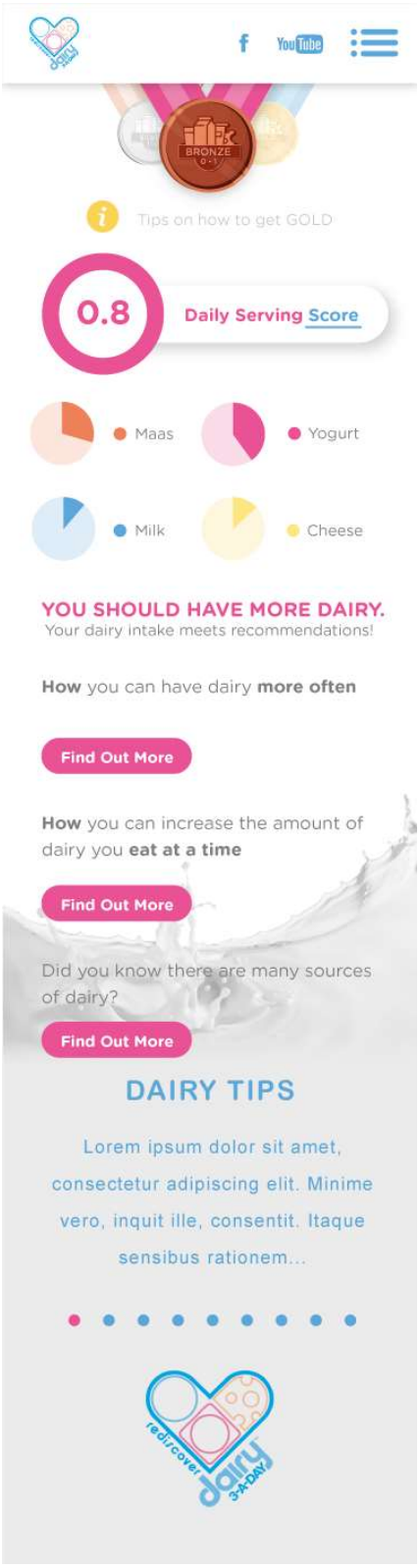
ANNEXURE C: THE DEVELOPMENT OF THE DAIRY DIARY

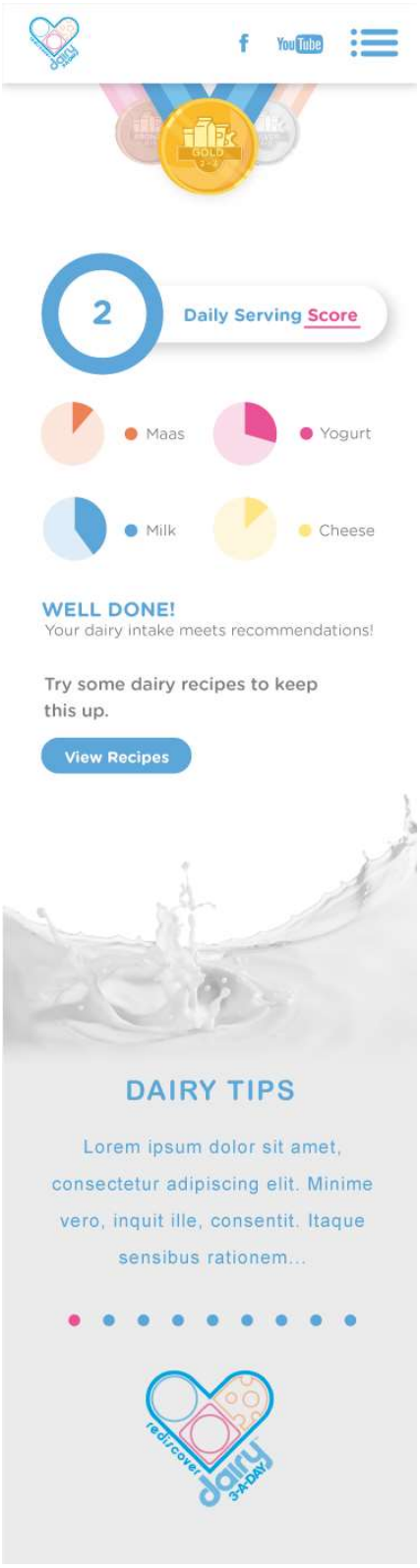
Images of the Type, Frequency and Amount of Milk in the Dairy Diary



Images of the Daily Serving Score with Bronze, Silver and Gold Medal Classification of the Dairy Diary







Images of Examples of the Preliminary Guidance Provided by the Dairy Diary

ANNEXURE D: USABILITY SUB-STUDY

Manuscript Publication in the *Journal of Dairy Research*

Journal of Dairy Research

cambridge.org/dar

Research Article

Cite this article: Piderit MC, White Z and Wenhold FAM (2022). The development and usability of a web-based mobile application as a dairy intake screener for South African adults. *Journal of Dairy Research* **89**, 453–460. https://doi.org/10.1017/S0022029922000802

Received: 6 July 2022
Revised: 27 October 2022
Accepted: 31 October 2022

Keywords:
Dairy; dietary screener; technology; uMARS; usability

Author for correspondence:
Monique C. Piderit,
Email: monique@nutritionalsolutions.co.za

The development and usability of a web-based mobile application as a dairy intake screener for South African adults

Monique C. Piderit, Zelda White and Friedeburg A. M. Wenhold

Department of Human Nutrition, Faculty of Health Sciences, University of Pretoria, Arcadia, South Africa

Abstract

Paper-based dietary assessment tools such as food frequency questionnaires (FFQ) and especially dietary screeners are making way for versions that use technology. Amidst low intakes of dairy and dairy-related nutrients in South Africa, and to increase public awareness thereof, we aimed to develop and evaluate the usability of an application (app) to screen for dairy intake in higher income South African adults. In a consultative process, a dairy intake screener ('Dairy Diary') was developed as an eight-item quantitative FFQ with four types of commonly consumed local dairy products: milk, maas (fermented milk), yoghurt, and cheese. For each dairy product, usual frequency of consumption and portion size per eating occasion were scored resulting in three risk classes: <1 serving daily; 1≤2 servings daily; ≥2 servings daily. Digitalisation included product- and portion-specific graphics with linkage to risk class-relevant preliminary dairy-related guidance as part of a web-based mobile app. For the evaluation of the usability, the 26-item end-user version of the Mobile Application Rating Scale (uMARS) was used in an online cross-sectional survey (Qualtrics; April 2020). Items were scored on a 5-point Likert-type scale, resulting in three final app scores. From a conveniently recruited sample of 1102, 703 (64%; 81% female; mean age 29.8 ± 11.0 years) were retained for analysis. uMARS-informed descriptive statistics summarise the findings. The uMARS app mean objective quality score (3.9 ± 0.85), app subjective quality score (3.5 ± 0.77), app-specific score (3.6 ± 0.94), and additional question on e-portion (4.3 ± 0.78) met the minimum acceptability score of ≥3.0. For the subscales, the mean score for aesthetics was the highest (4.4 ± 0.82), followed by information (4.3 ± 0.90) and functionality (4.0 ± 1.33). Engagement scored lowest (3.0 ± 1.55). The 'Dairy Diary' is a user-friendly screener for dairy intake.

In South Africa, dairy intake is low (Labadarios *et al.*, 1999; Mchiza *et al.*, 2015) and does not meet the daily recommendations as per the South African food-based dietary guidelines (Vorster *et al.*, 2013). Available evidence suggests a beneficial role of dairy in managing non-communicable diseases (such as heart disease and diabetes: Thorning *et al.*, 2017; Aljuraiban *et al.*, 2019; Guo *et al.*, 2019; Bhupathi *et al.*, 2020), in contributing to meeting gap nutrient intakes (Weaver, 2014), and in being a surrogate marker of diets higher in nutritional quality (Clerfeuille *et al.*, 2013; Rice *et al.*, 2013; Weaver, 2014).

Dietary screening (a short, focused, preliminary assessment of intake) is popular when information on total diet is not needed and when financial and/ or time constraints are applicable (Gurinovic *et al.*, 2017). Dietary screening may create awareness of poor intake, triggering a comprehensive dietary assessment (Field and Hand, 2015) and thus intervention by a nutrition professional. The food frequency questionnaire (FFQ) is a dietary assessment tool that assesses how often food items from a predetermined list are usually consumed within a specified reference period (Rodrigo *et al.*, 2015). In the quantitative version, portion sizes of the foods are also determined. Traditionally, dietary assessment tools were paper-based, but increasingly these are making way for technology-based versions in the form of web- and mobile-based applications (apps): software apps that can be executed (run) on a mobile platform (with or without wireless connectivity) or a web-based software app tailored to a mobile platform but executed on a server (U.S. Department of Health and Human Services, 2015).

The underlying methodology of dietary assessment is unchanged by technology (Sharp and Allman-Farinelli, 2014; Illner *et al.*, 2012), yet technology offers the potential of improved efficiency (Hongu *et al.*, 2011; Burrows and Rollow, 2019). Compared to traditional versions, a greater preference and satisfaction to use technology-based versions have been reported (Touvier *et al.*, 2011; Sharp and Allman-Farinelli, 2014; Hutchesson *et al.*, 2015; Timon *et al.*, 2017; Torre *et al.*, 2017; Burrows and Rollow, 2019). Flexibility, ease of access, reduced respondent burden, increased respondent co-operation, compliance, acceptance and greater appeal and relevance to a younger population are some of the strengths of web- and mobile-based apps (Hongu *et al.*, 2011; Gurinovic *et al.*, 2017; Illner *et al.*, 2012). Limitations include

high development and set up costs, the need for secure internet access and limited use in populations that are not familiar with technology, such as the elderly (Gurinovic *et al.*, 2017).

The initial evaluation of a dietary screener is typically in terms of usability: the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO, 1998). There is no consensus on the best tool to assess usability of mobile apps. The Mobile Application Rating Scale (MARS) (Stoyanov *et al.*, 2015) is a simple, objective tool to critically appraise the quality of health-related apps. Because MARS requires some training and expertise, a user-friendly version, the uMARS (Stoyanov *et al.*, 2016) was developed with excellent internal consistency ($\alpha = 0.90$) and high α for all subscales (engagement $\alpha = 0.80$; functionality $\alpha = 0.70$; aesthetics $\alpha = 0.71$; information $\alpha = 0.78$; satisfaction $\alpha = 0.78$). The total uMARS score and each individual subscale also have good test–retest reliability (Stoyanov *et al.*, 2016).

Accordingly, the first objective of this study was to develop a web-based mobile app ('Dairy Diary') as a tool to screen for dairy intake in South African adults, and the second objective was to evaluate the usability of the 'Dairy Diary' in two high income subgroups (consumers and nutrition professionals) using uMARS.

Materials and methods

The content and design of the dairy screener were compiled, reviewed, and revised in a consultative process by a working group of dietitians and nutritionists knowledgeable in consumer education related to dairy and/ or dietary assessment. The dietary screener is available online at the Consumer Education Project (CEP) of Milk South Africa (https://www.dairygivesyougo.co.za/dairy-diary)

Study design, population and sample, data collection tools

In a cross-sectional e-survey, data were collected by means of an online questionnaire (via Qualtrics). The population were South African adults (consumers and nutrition professionals) of high income (living standards measure, LSM, >8) aged 19–65 years with access to a computer and/or smartphone and internet. The LSM (http://www.eighty20.co.za/lsm-calculator/) is a widely used socioeconomic segmentation tool in South Africa for classifying consumers independent of race/ethnicity, sex, age or any other variable. Recruitment took place between March and April 2020. Participants were conveniently sampled *via* word of mouth and social media platforms associated with the University of Pretoria, professional dietetics and nutrition associations in South Africa (such as the Association for Dietetics in South Africa [ADSA]), and the Consumer Education Project (CEP) of Milk South Africa website ('Dairy Gives You Go').

First, participants completed the 'Dairy Diary' which calculates a daily serving score. Second, participants evaluated the 'Dairy Diary' using uMARS, with an additional question on portion sizes in an electronic format (e-portions) added. The uMARS (Stoyanov *et al.*, 2016) consists of 26 questions of three scores: app objective quality (four sub-scales of 16 items including 5 items on engagement, four on functionality, three on aesthetics and four on information), app subjective quality (four items) and app-specific score (six items adjusted to include questions to assess the perceived impact of the app on the user's knowledge, attitudes and intentions to change for the target health behaviour, i.e. dairy intake). Information on demographics (age, self-reported weight and height to calculate body mass index (BMI), gender), perceived health status and mobile app usage was collected. For nutrition professionals, additional information included recommended use of apps to patients, area of practice, reason for recommending app usage and opinion on the use of mobile apps compared to traditional (paper-based) methods for dietary assessment. A pilot study was conducted before commencement of data collection on eight participants (two nutrition professionals and six consumers), the participants of which were not included in the final analysis.

Data management and statistical analysis

Raw data were exported from Qualtrics in Microsoft Excel format. Data were cleaned for incomplete and/or missing responses, those with LSM <8 and those without informed consent. To calculate BMI, self-reported weight (kg) was divided by self-reported height (m) squared. Descriptive statistics of central tendency (means) and dispersion (SD and 95% CI) were applied for demographic information, the daily serving score and uMARS data. For the latter, all items were scored on a 5-point Likert-type scale (1 = inadequate; 2 = poor; 3 = acceptable; 4 = good, 5 = excellent; N/A = not applicable). Mean scores per item were reported instead of total scores as items may be rated as not applicable. The minimum mean acceptability score for the uMARS was ≥3.0 (Mani *et al.*, 2015). Data analyses were performed using Stata Release 15 (Release 15.1, College Station, TX: StataCorp LLC).

Ethical approval

The study was approved by the University of Pretoria Faculty of Health Sciences Research Ethics Committee (705/2018). Electronic informed consent was obtained, and all information was confidential. Participants voluntarily provided contact details to enter a random lucky draw to receive one of three online vouchers.

Results

Results of this study are described using the International Life Sciences Institute (ILSI) Europe Dietary Intake and Exposure Task Force Best Practice Guidelines (Elridge *et al.*, 2019) for reporting on dietary intake assessment tools using new technologies. Steps 1–4 are used for the development and step 5 for the usability of the dairy intake screener.

Step 1: purpose of the tool

The main purpose of the 'Dairy Diary' is to screen for and identify consumers at risk of low dairy intake. The dietary screener is for direct consumer use. South African adult consumers of higher income and nutrition professionals were the primary target group in this study.

Step 2: main measurement features of the tool

A quantitative FFQ format was chosen for the 'Dairy Diary'. Participants were prompted to consider habitual dietary intake of dairy products, usually consumed as a snack or meal, eaten at or away from home and/ or eaten alone or as part of a meal over the previous month. Assisted data entry allowed the user

to select frequency of consumption and portion size from predefined options. Additional items could not be entered into the 'Dairy Diary'. For each dairy product, customisation included visual representation of portion sizes (eg cup measures for milk, maas, a widely consumed fermented milk in South Africa, yoghurt and soft cheese but slices for hard cheese), supplemented with text indicating various ranges in volumes and cup measures (up to ½ cup, ½–1 cup, more than 1 cup) (online Supplementary Fig. S1). The user was able to return to previous screens, as necessary. Once digitalised, graphic enhancement was added. No further supplementary information on physical activity or dietary supplementation was collected.

Step 2: main measurement features of the tool: food list

The food list is the backbone of the FFQ (Cade *et al.*, 2004; Shim *et al.*, 2014). Three dairy products specified in the relevant South African food-based dietary guideline ('*Have milk, maas and yoghurt every day*') (Vorster *et al.*, 2013), plus cheese, all represented generically, formed the four dairy products and basis of the FFQ. Additional data were collected about the form of dairy product consumed: milk (reduced fat or full cream), maas (reduced fat or full cream), yoghurt (plain or flavoured), and cheese (hard or soft) (online Supplementary Fig. S1). This resulted in a final food list of eight items.

Step 2: main measurement features of the tool: frequency score

For each dairy product, the frequency (number of times) of consumption was assessed in four frequency categories: never, per day (0–3 times), per week (1–6 times), or per month (1–3 times). Each frequency category was converted into a daily intake amount. To score daily intake amounts, the frequency per day was defined by a factor of 1 (ie if the user indicated drinking milk twice a day, the factor is 2/1). To score weekly amounts, the frequency per week was defined by a factor of 7 (ie if the user indicated eating yoghurt three times per week, the factor is 3/7). To score monthly amounts, the frequency per month was defined by a factor of 30.417: the average number of days per month in a calendar year (ie if the user reported consuming maas twice per month, the factor is 2/30.417).

Step 2: main measurement features of the tool: serving score

The portion size consumed per eating occasion for each dairy product was shown as text and with quantifiable graphics, indicated as 'little', 'medium', or 'lots', defined as 50%, 75%, and 100% or more of a reference serving, respectively. The CEP of Milk SA defines the reference serving size of dairy as an amount containing 300 mg of calcium. For milk and maas, portions were scored as 0.5 for intake up to ½ cup, 0.75 for intakes ½–1 cup, or 1.0 for intakes more than 1 cup. For yoghurt, portions were scored as 0.5 for intakes of 1 small tub (100 ml), 0.75 for intakes of 1 cup, or 1 for intakes of more than 1 cup. For hard cheese, portions were scored as 0.5 for 1 slice (up to 20 g), 0.75 for 2 slices (20–40 g), or 1.0 for 3 slices (more than 40 g). For soft cheese, portions were scored as 0.5 for up to ¼ tub (60 g), 0.75 for ¼–½ tub (60–125 g), or 1.0 for intakes of more than 1 tub (125 g) (Table 1).

Step 2: main measurement features of the tool: daily serving score

A dairy product score was calculated for each dairy product by multiplying the frequency score by the portion score. The daily

Table 1. Calculations underpinning the daily serving score

Dairy product	Items in Dairy Diary	Method of eating/drinking	Frequency score: A[a] How often per day?				Serving score: B How much per eating occasion?			Dairy product[b] score = A×B
			Never	Per day	Per week	Per month	Little (Serving score: 0.5)	Medium (Serving score: 0.75)	Lots (Serving score: 1.0)	
Milk	Reduced fat[c] Full cream	As a drink on its own	0	Once: 1/1 Twice: 2/1 Three times: 3/1	Once: 1/7 Twice: 2/7 Three times: 3/7 Four times: 4/7 Five times: 5/7 Six times: 6/7	Once: 1/30.417 Twice: 2/30.417 Three times: 3/30.417	Up to ½ cup	½–1 cup	>1 cup	1
		In tea and coffee	0				<30 ml	30–50 ml	>50 ml	
		Cereal/porridge	0				<½ cup	½–1 cup	>1 cup	
		Flavoured milk	0				<½ cup	½–1 cup	>1 cup	
		Milky dessert e.g. custard	0				<½ cup	½–1 cup	>1 cup	
Maas	Reduced fat;[c] full cream	N/A	0				<½ cup	½–1 cup	>1 cup	2
Yoghurt	Flavoured; plain	N/A	0				1 small tub (100 ml)	1 cup (200–250 ml)	>1 cup (250 ml)	3
Cheese	Hard	N/A	0				1 slice (<20 g)	2 slices (20–40 g)	3 slices (>40 g)	4
	Soft	N/A	0				<¼ cup (60 g)	>¼ tub (60–125 g)	>1 tub (125 g)	
Daily serving score[d]										= 1 + 2 + 3 + 4

[a]Reported frequency of intake converted to intake per day. Examples: To score daily amounts, the reported frequency of intake per day was divided by a factor of 1 (i.e. if the user indicated drinking milk twice a day, the daily amount is 2/1). To score weekly amounts, the reported frequency of intake per week was divided by a factor of 7 (i.e. 7 d per week i.e. if the user indicated eating yoghurt three times per week, the daily amount is 3/7). To score monthly amounts, the reported frequency of intake per month was divided by a factor of 30.417: the average number of days per month in a calendar year (i.e. if the user reported consuming maas twice per month, the daily amount is 2/30.417).
[b]Dairy product score: for each dairy product, frequency score (A) multiplied by serving score (B).
[c]Includes fat-free and low fat.
[d]Daily serving score: sum of the dairy product scores (1–4).

Table 2. The daily serving score[a] of the study participants ($n = 703$)

Dairy product	Mean intake[a]	SD[b]	Min	Max	95% CI[c]
Milk	1.00	0.74	0.0	4.71	0.95–1.06
Maas	0.10	0.21	0.0	2.50	0.48–0.80
Yoghurt	0.41	0.51	0.0	3.75	0.38–0.45
Cheese	0.53	0.55	0.0	3.67	0.49–0.57
Daily serving score[d]	2.01	1.37	0.0	14.64	1.91–2.11

[a]Mean intake :Average dairy product score for sample ($n = 703$).
[b]SD: standard deviation.
[c]CI: confidence interval.
[d]Daily serving score: sum of the four dairy product scores, calculated for each dairy product by multiplying frequency score by portion score.

serving score was the sum of the dairy product scores (Table 1). The daily serving score was classified into three risk classes (<1 serving daily, 1≤2 servings daily, or ≥2 servings daily), guided by recommendations to consume at least 2 servings of dairy per day (Weaver, 2014). Maximum actual products serving scores for milk, maas, yoghurt, cheese and the daily serving score were 4.71, 2.50, 3.75, 3.67 and 14.64, respectively (Table 2). The theoretical maximum daily serving score was 24.47.

Step 3: platform/technology of the tool

The final content was converted to a digital version, executed on a web browser from an internet-connected device such as a smartphone, tablet, laptop, or computer. This platform was deemed appropriate for the population as data costs in South Africa are high, which may deter users from downloading the screener in a mobile app format. The development costs of a mobile app were another consideration.

Step 4: customisation features of the tool

A predetermined list of local dairy products with household measures (supplemented with images) form the basic customisation features of the screener (online Supplementary Fig. S1). Feedback included preliminary nutritional education ('Dairy Tips') linked to the participant's daily serving score. This consisted of consumer-friendly, targeted dairy-related information to support and encourage increased dairy intake or to maintain current intake. No further customisation features were available.

Step 5: evaluation of the usability of the 'Dairy Diary' with uMARS: description of sample

In total, 1102 responses were received. From these, a complete data set was available for 703 (64%) participants (online Supplementary Fig. S2). The majority of participants ($n = 573$; 82%) were consumers whereas the remaining 130 were nutrition professionals. The participants had a mean ± SD age of 29.8 ± 11.0 years and BMI of 24.9 ± 5.2 kg/m^2. The majority of participants (81%) were female and more than half (57%) had a healthy BMI (18.5–24.9 kg/m^2). Approximately one-third of the participants (32%) heard of the 'Dairy Diary' through contacts at the University of Pretoria and almost all (95%) had completed the 'Dairy Diary' for the first time, many of them (54%) on a smartphone. More than two-thirds (68%) of participants reported being 'very healthy' and 22% reported using nutrition- or health-related apps 'daily (or mostly daily)' (Table 3).

Table 3. Demographic and background information of the study participants ($n = 703$)

Background characteristics[a]			*n*	%
Sex	Female		568	80.8
	Consumer ($n = 73$)	Female	440	76.8
	Nutrition professional ($n = 130$)	Female	128	98.5
BMI category[b] (WHO, 2004)	Underweight		30	4.3
	Healthy weight		399	56.8
	Overweight		175	24.9
	Obese		99	14.1
How did you hear about the 'Dairy Diary'?	Network at University of Pretoria		222	31.6
	From a dietitian/healthcare professional		150	21.3
	From a friend/colleague		109	15.5
	From a professional organisation		80	11.4
	From my company/ employer		55	7.8
	On the 'Dairy Gives You Go' website		49	7.0
	Facebook		38	5.4
How many times have you completed the 'Dairy Diary'?	Once		664	94.5
	Twice		27	3.8
	Three times		8	1.1
	More than three times		4	0.6
How are you completing this questionnaire?	On a smartphone		380	54.1
	On a desktop/laptop		323	45.9
	On a tablet		0	0.0
In general, how is your health?	Very healthy		478	68.0
	Somewhat healthy		216	30.7
	Not healthy		9	1.3
How often do you personally use nutrition- and health-related apps?	Daily (or almost daily)		155	22.1
	Weekly		126	17.9
	Monthly		72	10.2
	Hardly ever		350	49.8

[a]Self-report with online questionnaire. BMI (body mass index): self-reported weight (kg) divided by self-reported height (m) squared.
[b]Underweight: <18.5 kg/m^2; Healthy weight: 18.5–24.9 kg/m^2; Overweight: 25.0–29.9 kg/m^2; Obese: >30.0 kg/m^2.

Almost all (99%) of the nutrition professionals were female and many (46%) worked in private practice, with 60% of these recommending nutrition- and health-related apps to their patients/clients. The most common reason for recommending the use of an app included 'for patient self-monitoring' (50%), 'to increase awareness' (41%), and 'for motivation and extra

Table 4. Descriptive information of the nutrition professionals ($n = 130$).

Background characteristic		*n*	%[a]
Sex	Female	128	98.5
Do you recommend nutrition- and health-related apps to patients/clients?	Yes	78	60.0
What area do you mostly work in?	Private practice	60	46.2
	Government	23	17.7
	University/tertiary education	12	9.2
	I no longer practice as a dietitian	9	6.9
	Corporate/food industry	8	6.2
	Research	5	3.9
	Community setting	4	3.1
	Other[b]	9	6.9
Why do you recommend your patients/clients use health- and nutrition-related apps?[c]	For self-monitoring	65	50.0
	To increase awareness	53	40.8
	For motivation and extra support	47	36.2
	For goal setting	40	30.8
	As an information resource	39	30.0
	I do not recommend apps	26	20.0
	As a dietary assessment tool	24	15.5
	To reduce time during consultations	1	0.8
How do you know which health- and nutrition-related apps to recommend?[c]	From personal use of apps	86	66.2
	From recommendations from other dietitians and healthcare professionals	71	54.6
	From recommendations from my patients/clients	29	22.3
In your opinion, how do mobile apps compare to traditional (paper-based) methods for dietary assessment?	Mobile apps are better than traditional methods for dietary assessment	48	36.9
	Mobile apps are equivalent to traditional methods for dietary assessment	61	46.9
	Mobile apps are worse than traditional methods for dietary assessment	21	16.2

[a]Percentage of affirmative.
[b]Includes unemployed, food service management, medical/pharmaceutical representative, clinical, and non-profit organisations.
[c]Participants could select more than one option.

support' (36%). Respectively, 37% and 47% of nutrition professionals rated mobile apps as being 'better' or 'equivalent' to traditional methods for dietary assessment (Table 4).

Step 5: evaluation of the usability of the 'Dairy Diary' with uMARS: usability

For uMARS, the mean app objective quality score (3.9 ± 0.85), app subjective quality score (3.5 ± 0.77), app specific mean score (3.6 ± 0.94) and the additional question on e-portions (4.3 ± 0.78) met the minimum acceptability criteria of ≥3.0 (Mani *et al.*, 2015). For the subscales, layout (4.5 ± 1.0) and aesthetics (4.4 ± 0.80) scored highest, followed by information (4.3 ± 0.90) and functionality (4.0 ± 1.30). Engagement (3.0 ± 1.55) and willingness to pay for the app (2.27 ± 0.99) and customisation (2.05 ± 1.71) scored low (Table 5).

Discussion

South Africa leads the number of mobile app downloads in Africa (GSMA, 2019). Approximately 62% of South African consumers own a connected mobile device and 21% use the device to access healthcare information (Global Mobile Consumer Survey, 2017). Considering low dairy intakes in South Africa and the growing trend of smartphone usage, screening for dairy intake may increase awareness and consumption of dairy, thereby initiating, motivating and driving behavioural change to raise awareness of and improve low dairy intakes. Thus, we have described the development of the 'Dairy Diary', a web-based mobile app which includes an eight-item food list with portion size to calculate total daily dairy intake. Further to this, we evaluated the usability of the 'Dairy Diary' using uMARS (Stoyanov *et al.*, 2016).

Whilst many dietary screeners exist to assess for calcium intake in adults (Magarey *et al.*, 2014), few dairy intake screeners exist with a food only focus (as opposed to nutrient and/ or food focus). In 1995, the dairy questionnaire (DQ: Welten *et al.*, 1995) was developed as a traditional (paper-based) quantitative screener to estimate the calcium intake from dairy products in young adults (27–29 years). The DQ, also in a quantitative FFQ format, shows moderate to good reliability and is considered valid for the assessment of calcium intake from dairy products. Other dairy intake screeners by Angbratt and Möller (1999), Gans *et al.* (2006) and Goldbohm *et al.* (2011) also assessed both calcium and dairy intake.

Table 5. The uMARS scale, sub-scales and items: mean and total score for the sample ($n = 703$)

Sub-scale	Item	Mean	SD
1. App mean objective quality score[a]		3.90	0.85
Engagement	1. Entertainment	3.23	1.38
	2. Interest	3.53	1.43
	3. Customisation	2.05	1.71
	4. Interactivity	2.46	1.69
	5. Target group	3.86	1.54
	Engagement Mean Score	3.03	1.55
Functionality	6. Performance	4.07	1.54
	7. Ease of use	4.13	1.36
	8. Navigation	3.79	1.45
	9. Gestural design	3.85	1.86
	Functionality Mean Score	3.96	1.33
Aesthetics	10. Layout	4.51	0.95
	11. Graphics	4.26	1.00
	12. Visual appeal	4.26	0.89
	Aesthetics Mean Score	4.35	0.82
Information	13. Quality of info	4.28	0.97
	14. Quantity of info	4.21	1.17
	15. Visual info	4.37	1.05
	16. Credibility of source	4.20	1.19
	Information Mean Score	4.27	0.90
2. App mean subjective quality score		3.49	0.77
Subjective quality	17. Recommend the app	3.71	1.24
	18. App use in one year	4.30	1.31
	19. Pay for app	2.27	0.99
	20. Overall star rating	3.69	0.72
3. App-specific mean score		3.56	0.94
App-specific	21. Awareness	3.82	1.05
	22. Knowledge	3.84	1.05
	23. Attitudes	3.46	1.11
	24. Intention to change	3.44	1.14
	25. Help seeking	3.47	1.18
	26. Behaviour change	3.31	1.19
Additional question on e-portions		4.27	0.78

[a]Mean of four objective sub-scales of 26 items: engagement (five items), functionality (four items), aesthetic (three items) and information (four items).

In Southern Africa, to the author's knowledge, dairy intake screeners do not exist. Thus, the 'Dairy Diary' is an original, novel and local technology-based dairy intake screener. With growing interest in technology-based dietary screening tools, evaluating the usability of dietary screeners is essential. Results from this study showed that the three mean scores in uMARS each met the minimum acceptable score of ≥3.0 (Mani *et al.*, 2015). The app objective quality mean score was the highest scoring domain, followed by the app specific mean score, and app subjective quality score. The functionality score was the highest and the engagement score was the lowest. This indicates the user's preference towards favouring input and participation when utilising the app. The same pattern of high functionality and low engagement has been reported in other studies using uMARS (LeBeau *et al.*, 2019; Davalbhakta *et al.*, 2020). LeBeau *et al.* (2019) evaluated 25 mobile apps used by occupational therapists, and Davalbhakta *et al.* (2020) evaluated 63 COVID-19 related apps. In both studies, high functionality and low engagement scores were reported.

Participants scored the layout of the 'Dairy Diary' the highest, followed by visual information. This suggests that participants value the aesthetic and visual appeal of the dietary screener, implying participants desire the opportunity to adapt and personalise the dietary screener, an observation which may be particularly relevant to the nutrition professional. In this study, participants scored high on the subscales of information, quality of information, quantity of information and credibility of the source. To the contrary, when evaluating nutrition-related apps in Brazil, Braz and Lopes (2018) found that mobile apps were not based on reliable sources of information. This was supported by Byambasuren *et al.* (2019) where 16% of Australian general practitioners reported a lack of trustworthy sources as a barrier to prescribing apps in practice.

Customisation and willingness to pay for the appscored lowest, suggesting that users may be less inclined to use the app if payment was requested. Accordingly, future considerations to enhance user participation may include more customisation options for the 'Dairy Diary' to tailor to the user's preferences. Future research may also evaluate the usability of the 'Dairy Diary' in different age and gender groups. In addition, planners of public health initiatives may benefit from the outcome of the 'Dairy Diary' to screen for low dairy intakes among the general public. It may also be valuable to evaluate the usability of a traditional (pen and paper) version of the 'Dairy Diary' in these different populations.

For nutrition professionals, the 'Dairy Diary' may be a simple and practical tool to screen for low dairy intakes, driving dairy-related nutrition education. Such a tool may serve as a trigger into the nutrition care process for more comprehensive dietary assessment. Including apps into dietetic practice could enhance the efficiency and quality of nutrition care and counselling, supporting that nutrition professionals play a leading role in the development of such dietary screeners (Chen *et al.*, 2018). For this reason, the study population included a sub-group of nutrition professionals in South Africa.

To the authors' knowledge, nutrition- and health-related mobile app use among South African nutrition professionals is unknown. In the present study, 60% of nutrition professionals recommend app usage to patients, with two-thirds basing their recommendation from personal use of the apps. Higher proportions (79%) of mobile app usage have been reported in American dietitians (Sharman and Ashbury, 2015), as well as in the Clinician Apps Survey (85%: Karduck and Chapman-Novakofski, 2018). Sauceda *et al.* (2016) reported 83% of healthcare providers recommend nutrition- or health-related apps to patients. Lower mobile app recommendations have been reported in an international survey of healthcare professionals from 73 countries (46%: Vasiloglou *et al.*, 2020). Canadian dietitians (57%: Lieffers *et al.*, 2014), Irish dietitians (42%: Timon, 2018) and sports dietitians in Australia, Canada, New Zealand, United States and the United Kingdom (32%: Jospe *et al.*, 2015) likewise have shown lower usage.

In South Africa, mobile data costs are among the highest in the world (Moyo and Munoriyarwa, 2021), despite 83% smartphone penetration in 2018 (nearly double that of 2016: ICASA, 2019). At the same time, internet and fibre-to-the-home/building internet subscriptions increased by 42% and 279%, respectively (ICASA, 2019). High mobile data costs may potentially explain lower app recommendation by nutrition professionals in South Africa compared to other countries, despite increased internet access.

Jospe *et al.* (2015) found that dietitians describe apps as 'better' (47%) or 'equivalent' (41%) to traditional dietary assessment methods. In our study, results were similar with 37% and 47% of dietitians reporting that mobile apps are 'better' or 'equivalent to' traditional methods for dietary assessment, respectively. The generalisability of this study may be considered limited in that three-quarters of consumers and almost all of the nutrition professionals were female. Traditionally, the nutrition profession is known to be mostly female, as supported by the Association of Dietetics in South Africa (ADSA) membership profile with 97.1% being female (ADSA, 2022). The evaluation of the usability may also be different in lower LSM groups. Thus, it may be pertinent to evaluate the usability of the 'Dairy Diary' in other populations.

In conclusion, as evaluated by uMARS, the 'Dairy Diary' is a technology-based, user-friendly dairy intake screener. For a dietary screening tool to be of value, its performance needs to be assessed in terms of reliability and validity. If reliable and valid, such a screener may contribute to the cost-effective assessment of dairy intake. Future validation studies of the 'Dairy Diary' are recommended.

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Recruitment Advertisement for the Usability Study

Variables Used in the Eighty20 Calculator to Calculate LSM

1. Metropolitan dweller (> 250 000).
2. Living in a non-urban area.
3. House/cluster house/town house.
4. Tap water in house/on plot.
5. Flush toilet inside house.
6. Hot running water.
7. Built in kitchen sink.
8. No domestic workers or gardeners.
9. Home security service.
10. Two cell phones in household.
11. One or more cell phones in household.
12. Zero or one radio set in household.
13. Air conditioner (excl. fans).
14. Television set(s).
15. Swimming pool.
16. DVD player/Blu-ray player.
17. Refrigerator or combined fridge/freezer.
18. Electric stove.
19. Microwave oven.
20. Deep freezer – free standing.
21. Washing machine.
22. Tumble dryer.
23. Dishwasher.
24. PayTV (M-Net/DSTV/TopTV) subscription.
25. Home theatre system.
26. Vacuum cleaner.
27. Motor vehicle in household.
28. Computer – desktop/laptop.
29. Landline telephone (excl. cell phone).

Data Collection Tool Executed on Qualtrics

SECTION 1: INFORMED CONSENT

Usability and Validity of a Dairy Intake Screener as a Web-based Mobile Application for South African Adults

Principal Investigator: Monique Piderit, RD (SA)

Supervisors: Prof. FAM Wenhold, Dr Z White

Dear Prospective Research Participant,

INTRODUCTION You are invited to volunteer for a research study. I am doing this research as part of my PhD (Dietetics) at the University of Pretoria. The information below is provided to help you to decide whether you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions that are not fully explained below, do not hesitate to ask the researcher/recruiter. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

THE NATURE AND PURPOSE OF THIS STUDY The results of this study will help dietitians to better measure the dairy intake of South Africans.

EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS You will complete an online questionnaire. This will take approximately 5 minutes. We will collect your answers when you submit the last question. The answers from the Dairy Diary that you have just completed will be linked to the questionnaire. We will not be available to help you with the questionnaire. The researcher will keep the completed online questionnaire in a safe place to make sure that only people working on the study have access to the data.

The questionnaire consists of two sections:

1. *Section 1 – the Dairy Diary:* You completed Section 1 when you did the Dairy Diary. The Dairy Diary calculates a daily serving score for dairy. For the purpose of this study, this score has been hidden. Feedback from the researcher on your daily serving score can be made

available after the study. This is entirely voluntary and will require that you enter your contact details at the end of the questionnaire.

2. *Section 2 – Demographic Information:* This involves answering some questions about your age, gender, weight and height, and app usage.

RISK AND DISCOMFORT INVOLVED There are no foreseeable physical discomforts or risks involved. If there are questions that are too sensitive for you to answer, you do not need to answer them.

POSSIBLE BENEFITS OF THIS STUDY This study may help you learn more about your own dairy intake and how to incorporate dairy into your diet.

ETHICS APPROVAL This protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4–59, telephone numbers (012) 356 3084/(012) 356 3085. Written approval has been granted by that committee (protocol number 705/2018). The study has been structured in accordance with the Declaration of Helsinki (last updated October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the declaration may be obtained here should you wish to review it.

INFORMATION If you have any questions concerning this study, you may contact Monique Piderit: 072 381 5282/s28020945@tuks.co.za.

CONFIDENTIALITY All records from this study will be regarded as confidential. All results will be published or presented in such a way that it is not possible to identify you as a participant. Information gathered in this study is for research purposes only and will not be used for marketing purposes. You will indicate your participant code in the completion of the Dairy Diary. The researcher will keep a list of these participant codes and your student number in the event that you forget your participant code.

COMPENSATION You will not be paid to take part in the study.

CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have received, read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I am aware that information shared in this study is for research purposes only and will not be used for marketing purposes.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and my withdrawal will not affect my employment or student status.
- I am participating willingly. I have received a copy of this informed consent agreement, on request.

To continue, please indicate YES or NO, and then select the blue arrow on the bottom right of the page.

SECTION 2: INFORMATION ABOUT YOU

Thank you for agreeing to take part in this study. You can complete this questionnaire on your desktop, laptop, smartphone or tablet. We would like to know more info about you. Please indicate the most applicable answer to each question. This section should take about 5–10 minutes.

Question*	**Possible answers**
7. Tick the boxes that apply to you and your household. *If LSM < 8, discontinue study.*	7 Insert LSM calculator from http://www.eighty20.co.za/lsm-calculator/
8. How did you hear about the Dairy Diary?	8.1 On the Dairy Gives You Go website. 8.2 From a friend or colleague. 8.3 From my dietitian. 8.4 ADSA. 8.5 DIP. 8.6 From my company/employer. 8.7 Other (please specify).
9. How many times have you completed the Dairy Diary in total?	9.1 Once. 9.2 Twice. 9.3 Three times. 9.4 More than three times.
10. How are you completing this questionnaire?	10.1 On a desktop/laptop. 10.2 On a smartphone. 10.3 On a tablet.
11. How old are you?	11. _____
12. What is your gender?	12.1 Male. 12.2 Female.
13. In general, how is your health?	13.1 I am very healthy. 13.2. I am somewhat healthy. 13.3. I am not healthy.
14.1 Please indicate your weight in kilogram. 14.2 Please indicate your height in metre.	14.1 _____ 14.2 _____
15. How often do you personally use nutrition and health-related apps?	15.1 Daily (or almost daily). 15.2 Weekly. 15.3 Monthly. 15.4 Hardly ever.
16. Which nutrition and health-related apps have you personally used in the past 3 months? Tick as many as apply to you.	16.1 MyFitnessPal. 16.2 Calorie Counter. 16.3 FatSecret. 16.4 DietMate/DietMate Pro.

Question*	Possible answers
	16.5 Lose It! 16.6 Fit Bit. 16.7 Samsung Health. 16.8 Monash Low FODMAP Diet. 16.9 Other (please specify). _____
17. Please tick the most appropriate answer.	17.1 I am a consumer. 17.2 I am a registered dietitian. 17.3 I am a dietetics/nutrition student in first year. 17.4 I am a dietetics/nutrition student in second year. 17.5 I am a dietetics/nutrition student in third year. 17.6 I am a dietetics/nutrition student in fourth year.
18. What area of dietetics do you work in? *If answered 17.2 (dietitian).*	18.1 Public service. 18.2 Private practice. 18.3 Academia. 18.4 Foodservice management. 18.5 Food industry. 18.6 I no longer practice as a dietitian. 18.7 Other (Please specify).
19. Do you recommend nutrition and health-related apps to patients/consumers? *If answered 17.2 (dietitian).*	19.1 No. 19.2 Yes.
20. Why do you recommend your patients/ clients use health and nutrition-related apps? Choose as many as applicable. *If answered 17.2 (dietitian).*	20.1 For goal setting. 20.2 For self-monitoring. 20.3 To increase awareness. 20.4 As an information resource. 20.5 For motivation and extra support. 20.6 As a dietary assessment tool. 20.7 To reduce time during consultations. 20.8 Other (please specify).
21. How do you know which health- and nutrition-related apps to recommend? *If answered 17.2 (dietitian).*	21.1 From personal use of the apps. 21.2 From recommendations from my patients/ consumers. 21.3 From recommendations from other dietitians and healthcare professionals.
22. In your opinion, how do mobile apps compare to traditional (paper-based) methods for dietary assessment? *If answered 17.2 (dietitian).*	22.1 Mobile apps are ***better*** than traditional methods for dietary assessment. 22.2 Mobile apps are ***equivalent*** to traditional methods for dietary assessment.

Question*	Possible answers
	22.3 Mobile apps are ***worse*** than traditional methods for dietary assessment.

*Question 1 – 6 are in section 2 of the questionnaire

SECTION 3: EVALUATE THE DAIRY DIARY

You've just completed the Dairy Diary. We would now like your help in evaluating how user-friendly it is. There are six (6) sections to this part of the study. Choose the number that most accurately represents your experience of the Dairy Diary. All items are rated on a five-point scale from 1 (worst) to 5 (best). Select not applicable (N/A) if the answer is not relevant. This section should take about 10–15 minutes.

Question	Possible answers	Office use
1. Engagement		
23. **Entertainment:** Is the app fun/entertaining to use? Does it have components that make it more fun than other similar apps?	23.1 Dull, not fun or entertaining at all. 23.2 Mostly boring. 23.3 OK, fun enough to entertain user for a brief time (< 5 minutes). 23.4 Moderately fun and entertaining, would entertain user for some time (5–10 minutes total). 23.5 Highly entertaining and fun, would stimulate repeat use. 23.6 N/A.	23
24. **Interest:** Is the app interesting to use? Does it present its information in an interesting way compared to other similar apps?	24.1 Not interesting at all. 24.2 Mostly uninteresting. 24.3 OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes). 24.4 Moderately interesting; would engage user for some time (5–10 minutes total). 24.5 Very interesting, would engage user in repeat use. 24.6 N/A.	24
25. **Customisation:** Does the app allow you to customise the settings and preferences that you would like to (e.g. sound, content and notifications)?	25.1 Does not allow any customisation or requires setting to be input every time. 25.2 Allows little customisation and that limits app's functions. 25.3 Basic customisation to function adequately. 25.4 Allows numerous options for customisation. 25.5 Allows complete tailoring the user's characteristics/preferences, remembers all settings.	25

Question	Possible answers	Office use
	25.6 N/A.	
26. **Interactivity**: Does it allow user input, provide feedback, contain prompts (e.g. reminders, sharing options, and notifications)?	26.1 No interactive features and/or no response to user input. 26.2 Some, but not enough interactive features which limits app's functions. 26.3 Basic interactive features to function adequately. 26.4 Offers a variety of interactive features, feedback and user input options. 26.5 Very high level of responsiveness through interactive features, feedback and user input options. 26.6 N/A.	26
27. **Target group:** Is the app content (visuals, language, design) appropriate?	27.1 Completely inappropriate, unclear or confusing. 27.2 Mostly inappropriate, unclear or confusing. 27.3 Acceptable but not specifically designed for the target audience. May be inappropriate/unclear/confusing at times. 27.4 Designed for the target audience, with minor issues. 27.5 Designed specifically for the target audience, no issues found. 27.6 N/A.	27
2. Functionality		
28. **Performance**: How accurately/fast does the app features (functions) and components (buttons/menus) work?	28.1 App is broken. No/insufficient/inaccurate response (e.g. crashes/bugs/broken features). 28.2 Some functions work, but lagging or contains major technical problems. 28.3 App works overall. Some technical problems need fixing, or is slow at times. 28.4 Mostly functional with minor/negligible problems. 28.5 Perfect/timely response; no technical bugs found, or contains a 'loading time left' indicator (if relevant). 28.6 N/A.	28
29. **Ease of use:** How easy is it to learn how to use the app? How clear are the menu labels, icons and instructions?	29.1 No/limited instructions; menu labels, icons are confusing; complicated. 29.2 Takes a lot of time or effort. 29.3 Takes some time or effort. 29.4 Easy to learn (or has clear instructions). 29.5 Able to use app immediately; intuitive; simple (no instructions needed). 29.6 N/A.	29
30. **Navigation**: Does moving between screens make sense? Does app have all	30.1 No logical connection between screens at all/navigation is difficult. 30.2 Understandable after a lot of time/effort. 30.3 Understandable after some time/effort.	30

Question	Possible answers	Office use
necessary links between screens?	30.4 Easy to understand/navigate. 30.5 Perfectly logical, easy, clear and intuitive screen flow throughout, and/or has shortcuts. 30.6 N/A.	
31. **Gestural design:** Do tabs/swipes/pinches/ scrolls make sense? Are they consistent across all components/screens?	31.1 Completely inconsistent/confusing. 31.2 Often inconsistent/confusing. 31.3 OK with some inconsistencies/confusing elements. 31.4 Mostly consistent/intuitive with negligible problems. 31.5 Perfectly consistent and intuitive. 31.6 N/A.	31
3. Aesthetics		
32. **Layout:** Is arrangement and size of buttons, icons, menus and content on the screen appropriate?	32.1 Very bad design, cluttered, some options impossible to select, locate, see or read. 32.2 Bad design, random, unclear, some options difficult to select/locate/see/read. 32.3 Satisfactory, few problems with selecting/locating/seeing/reading items. 32.4 Mostly clear, able to select/locate/see/read items. 32.5 Professional, simple, clear, orderly, logically organised. 32.6 N/A.	32
33. **Graphics:** How high is the quality/resolution of graphics used for buttons, icons, menus and content?	33.1 Graphics appear amateur, very poor visual design – disproportionate, stylistically inconsistent. 33.2 Low quality/low resolution graphics; low quality visual design – disproportionate. 33.3 Moderate quality graphics and visual design (generally consistent in style). 33.4 High quality/resolution graphics and visual design – mostly proportionate, consistent in style. 33.5 Very high quality/resolution graphics and visual design – proportionate, consistent in style throughout. 32.6 N/A.	33
34. **Visual appeal:** How good does the app look?	34.1 Ugly, unpleasant to look at, poorly designed, clashing, mismatched colours. 34.2 Bad – poorly designed, bad use of colour, visually boring. 34.3 OK – average, neither pleasant, nor unpleasant. 34.4 Pleasant – seamless graphics – consistent and professionally designed. 34.5 Beautiful – very attractive, memorable, stands out; use of colour enhances app features/menus. 34.6 N/A.	34

Question	Possible answers	Office use
4. Quality of information		
35. **Quality of information:** Is app content correct, well written, and relevant to the goal/topic of the app (i.e. dairy)?	35.1 Irrelevant/inappropriate/incoherent/incorrect. 35.2 Poor. Barely relevant/appropriate/coherent/may be incorrect. 35.3 Moderately relevant/appropriate/coherent/and appears correct. 35.4 Relevant/appropriate/coherent/correct. 35.5 Highly relevant, appropriate, coherent, and correct. 35.6 N/A. There is no information within the app.	35
36. **Quantity of information:** Is the information within the app comprehensive but concise?	36.1 Minimal or overwhelming. 36.2 Insufficient or possibly overwhelming. 36.3 OK but not comprehensive or concise. 36.4 Offers a broad range of information, has some gaps or unnecessary detail; or has no links to more information and resources. 36.5 Comprehensive and concise; contains links to more information and resources. 36.6 N/A. There is no information within the app.	36
37. **Visual information:** Is visual explanation of concepts – through charts/graphs/ images/videos, etc. – clear, logical, and correct?	37.1 Completely unclear/confusing/wrong or necessary but missing. 37.2 Mostly unclear/confusing/wrong. 37.3 OK but often unclear/confusing/wrong. 37.4 Mostly clear/logical/correct with negligible issues. 37.5 Perfectly clear/logical/correct. 37.6 N/A. There is no visual information within the app (e.g. it only contains audio, or text).	37
38. **Credibility of source:** Does the information within the app seem to come from a credible source?	38.1 Suspicious source. 38.2 Lacks credibility. 38.3 Not suspicious but legitimacy of source is unclear. 38.4 Possibly comes from a legitimate source. 38.5 Definitely comes from a legitimate/specialised source. 38.6 N/A. There is no information within the app.	38
5. Subjective assessment		
39. Would you recommend this app to people who might benefit from it?	39.1 I would not recommend this app to anyone. 39.2 There are very few people I would recommend this app to. 39.3 Maybe There are several people I would recommend this app to. 39.4 There are many people I would recommend this app to. 39.5 Definitely I would recommend this app to everyone. 39.6 N/A.	39

Question	Possible answers	Office use
40. How many times do you think you would use this app in the next 12 months if it was relevant to you?	40.1 None. 40.2 1–2. 40.3 3–10. 40.4 10–50. 40.5 > 50. 40.5 N/A.	40
41. Would you pay for this app?	41.1 Definitely not. 41.2 Unlikely. 41.3 Maybe. 41.4 Likely. 41.5 Definitely yes. 41.6 N/A.	41
42. What is your overall (star) rating of the app?	42.1 * One of the worst apps I've used. 42.2 ** 42.3 *** Average. 42.4 **** 42.5 ***** One of the best apps I've used. 42.6 N/A	42
6: Perceived impact		
43. **Awareness:** This app has increased my awareness of the importance of addressing my dairy intake.	43.1 Strongly disagree. 43.2 Disagree. 43.3 Neutral. 43.4 Agree. 43.5 Strongly agree. 43.6 N/A.	43
44. **Knowledge:** This app has increased my knowledge/ understanding of my dairy intake.	44.1 Strongly disagree. 44.2 Disagree. 44.3 Neutral. 44.4 Agree. 44.5 Strongly agree. 44.6 N/A.	44
45. **Attitudes:** The app has changed my attitudes toward improving my dairy intake.	45.1 Strongly disagree. 45.2 Disagree. 45.3 Neutral. 45.4 Agree. 45.5 Strongly agree. 45.6 N/A.	45

Question	Possible answers	Office use
46. **Intention to change:** The app has increased my intentions/motivation to address dairy intake.	46.1 Strongly disagree. 46.2 Disagree. 46.3 Neutral. 46.4 Agree. 46.5 Strongly agree. 46.6 N/A.	46
47. **Help seeking:** This app would encourage me to seek further help to address my dairy intake (if I needed it)	47.1 Strongly disagree. 47.2 Disagree. 47.3 Neutral. 47.4 Agree. 47.5 Strongly agree. 47.6 N/A.	47
48. **Behaviour change:** Use of this app will increase my dairy intake.	48.1 Strongly disagree. 48.2 Disagree. 48.3 Neutral. 48.4 Agree. 48.5 Strongly agree. 48.6 N/A.	48
7. Portion sizes		
49. Compared to physical portions, the electronic graphic/ images of portion sizes in the app were helpful.	49.1 Strongly disagree. 49.2 Disagree. 49.3 Neutral. 49.4 Agree. 49.5 Strongly agree. 49.6 N/A.	49
50. Time to completion of survey	50. _____	50

You have successfully completed the research survey. Thank you.

If you would like to be entered into a random draw to win one of three R1 000 online vouchers, please enter your name and contact details.

ANNEXURE E: VALIDITY SUB-STUDY

INFORMED CONSENT – FOOD RECORDS (NORTH-WEST UNIVERSITY)

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Principal investigator: Monique Piderit

Supervisor: Prof. FAM Wenhold, Dr Z White

Institution: University of Pretoria

Daytime contact number: 072 381 5282

Ethics protocol number: 705/2018

PARTICIPANT CODE:
NW_____

DATE AND TIME OF INFORMED CONSENT DISCUSSION:

			h
DD	**MONTH**	**YEAR**	**TIME**

Dear Prospective Research Participant,

1) INTRODUCTION

You are invited to volunteer for a research study. I am doing this research as part of my PhD (Dietetics) at the University of Pretoria. The information in this document is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

2) THE NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to collect information on your daily food intake. The results of this study will help dietitians to better measure a certain food group.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS

If you choose to take part, you will submit photocopies of the three-day weighed food records that you completed for your module assessment. The researcher will keep the photocopies of the food records in a safe place to make sure that only people working on the study will have access to it. This will ensure that your answers are kept confidential (so nobody will know what you have answered).

4) RISK AND DISCOMFORT INVOLVED

There are no foreseeable physical discomforts or risks involved. Choosing to take part in this study will not affect your student status or the mark for module assessment.

5) POSSIBLE BENEFITS OF THIS STUDY

This study may help give you more insight into your daily food intake.

6) ETHICS APPROVAL

This protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4–59, telephone numbers (012) 356 3084/(012) 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the declaration may be obtained from the investigator should you wish to review it.

7) INFORMATION

If you have any questions concerning this study, you may contact Monique Piderit: 072 381 5282/s28020945@tuks.co.za.

8) CONFIDENTIALITY

All information obtained during this study will be regarded as confidential. You will be allocated with a participant code (e.g. NW001, NW002) to allow the researcher to link your food records. The researcher will keep a list of these participant codes and your student number in the event that you forget your participant code. This will ensure confidentiality of information collected. Only the researcher will be able to identify you as participant. Results will be published or presented in such a fashion that you remain unidentifiable. The hard copies of all your records will be kept in a locked facility at the Department of Human Nutrition at the University of Pretoria.

9) COMPENSATION

You will not be paid to take part in the study. The electronic scales and batteries provided to you to complete the weighed food records need to be returned at the end of the study.

10) CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have received (on request), read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and that withdrawal will not affect my marks or student status.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.

Participant Name	**Participant Signature**	**Date**
Researcher Name	**Researcher Signature**	**Date**

INFORMED CONSENT – FOOD RECORDS (UNIVERSITY OF PRETORIA)

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Principal investigator: Monique Piderit

Supervisor: Prof. FAM Wenhold, Dr Z White

Institution: University of Pretoria

Daytime contact number: 072 381 5282

Ethics protocol number: 705/2018

PARTICIPANT CODE: UP_____

DATE AND TIME OF INFORMED CONSENT DISCUSSION:

			h
DD	**MONTH**	**YEAR**	**TIME**

Dear Prospective Research Participant,

1) **INTRODUCTION**

You are invited to volunteer for a research study. I am doing this research as part of my PhD (Dietetics) at the University of Pretoria. The information in this document is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

2) THE NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to collect information on your daily food intake. The results of this study will help dietitians to better measure a certain food group.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS

If you choose to take part, you will submit electronic copies of the three-day weighed food records that you completed for your module assessment (Nutritional Assessment 313/314). The researcher will keep the electronic copies of the food records in a safe place to make sure that only people working on the study will have access to it. This will ensure that your answers are kept confidential (so nobody will know what you have answered).

4) RISK AND DISCOMFORT INVOLVED

There are no foreseeable physical discomforts or risks involved. Choosing to take part in this study will not affect your student status or the mark for module assessment.

5) POSSIBLE BENEFITS OF THIS STUDY

This study may help give you more insight into your daily food intake.

6) ETHICS APPROVAL

This protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4–59, telephone numbers (012) 356 3084/(012) 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the declaration may be obtained from the investigator should you wish to review it.

7) INFORMATION

If you have any questions concerning this study, you may contact Monique Piderit: 072 381 5282/s28020945@tuks.co.za.

8) CONFIDENTIALITY

All information obtained during this study will be regarded as confidential. You will be allocated with a participant code (e.g. UP001, UP002) to allow the researcher to link your food records. The researcher will keep a list of these participant codes and your student number in the event that you forget your participant code. This will ensure confidentiality of information collected. Only the researcher will be able to identify you as participant. Results will be published or presented in such a fashion that you remain unidentifiable. The hard copies of all your records will be kept in a locked facility at the Department of Human Nutrition at the University of Pretoria.

9) COMPENSATION

You will not be paid to take part in the study. The electronic scales and batteries provided to you to complete the weighed food records need to be returned at the end of the study.

10) CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have received (on request), read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and that withdrawal will not affect my marks or student status.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.

Participant Name	**Participant Signature**	**Date**
Researcher Name	**Researcher Signature**	**Date**

INFORMED CONSENT – FOOD RECORDS (UNIVERSITY OF THE FREE STATE)

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT

STUDY TITLE: USABILITY AND VALIDITY OF A DAIRY INTAKE SCREENER AS A WEB-BASED MOBILE APPLICATION FOR SOUTH AFRICAN ADULTS

Principal investigator: Monique Piderit

Supervisor: Prof. FAM Wenhold, Dr Z White

Institution: University of Pretoria

Daytime contact number: 072 381 5282

Ethics protocol number: 705/2018

PARTICIPANT CODE: UF_____

DATE AND TIME OF INFORMED CONSENT DISCUSSION:

			h
DD	**MONTH**	**YEAR**	**TIME**

Dear Prospective Research Participant,

1) INTRODUCTION

You are invited to volunteer for a research study. I am doing this research as part of my PhD (Dietetics) at the University of Pretoria. The information in this document is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

2) THE NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to collect information on your daily food intake. The results of this study will help dietitians to better measure a certain food group.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS

If you choose to take part, you will use an electronic scale (such as the one provided in your dietary kit) to complete weighed food records for three days. You will also receive three booklets within which to record the food records. The researcher will keep the food records in a safe place to make sure that only people working on the study will have access to it. This will ensure that your answers are kept confidential (so nobody will know what you have answered).

4) RISK AND DISCOMFORT INVOLVED

There are no foreseeable physical discomforts or risks involved. Choosing to take part in this study will not affect your student status or the mark for module assessment.

5) POSSIBLE BENEFITS OF THIS STUDY

This study may help give you more insight into your daily food intake.

6) ETHICS APPROVAL

This protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4–59, telephone numbers (012) 356 3084/(012) 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the declaration may be obtained from the investigator should you wish to review it.

7) INFORMATION

If you have any questions concerning this study, you may contact Monique Piderit: 072 381 5282/s28020945@tuks.co.za.

8) CONFIDENTIALITY

All information obtained during this study will be regarded as confidential. You will be allocated with a participant code (e.g. UF001, UF002) to allow the researcher to link your food records. The researcher will keep a list of these participant codes and your student number in the event that you forget your participant code. This will ensure confidentiality of information collected. Only the researcher will be able to identify you as participant. Results will be published or presented in such a fashion that you remain unidentifiable. The hard copies of all your records will be kept in a locked facility at the Department of Human Nutrition at the University of Pretoria.

9) COMPENSATION

You will not be paid to take part in the study.

10) CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have received (on request), read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and that withdrawal will not affect my marks or student status.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.

Participant Name	**Participant Signature**	**Date**
Researcher Name	**Researcher Signature**	**Date**

INFORMED CONSENT – ADMINISTRATION OF THE DAIRY DIARY (NORTH-WEST UNIVERSITY, UNIVERSITY OF THE FREE STATE, UNIVERSITY OF PRETORIA)

Usability and Validity of a Dairy Intake Screener as a Web-based Mobile Application for South African Adults

University of Pretoria

Principal Investigator: Monique Piderit, RD (SA)

Supervisors: Prof. FAM Wenhold, Dr Z White

Dear Prospective Research Participant,

INTRODUCTION You are invited to volunteer for a research study. I am doing this research as part of my PhD (Dietetics) at the University of Pretoria. The information below is provided to help you to decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions which are not fully explained below, do not hesitate to ask the researcher/recruiter. You should not agree to take part unless you are completely happy with the kind of questions that will be asked.

THE NATURE AND PURPOSE OF THIS STUDY The results of this study will help dietitians to better measure the dairy intake of South Africans.

EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS You will complete an online questionnaire. This will take approximately 5 minutes. We will collect your answers when you submit the last question. The answers from the Dairy Diary that you have just completed will be linked to the questionnaire. We will not be available to help you with the questionnaire. The researcher will keep the completed online questionnaire in a safe place to make sure that only people working on the study have access to the data.

The questionnaire consists of two sections:

1. *Section 1 – the Dairy Diary:* You completed Section 1 when you did the Dairy Diary. The Dairy Diary calculates a daily serving score for dairy. For the purpose of this study, this score has been hidden. Feedback from the researcher on your daily serving score can be made

available after the study. This is entirely voluntary and will require that you enter your contact details at the end of the questionnaire.

2. *Section 2 – Demographic Information:* This involves answering some questions about your age, gender, weight and height, and app usage.

RISK AND DISCOMFORT INVOLVED There are no foreseeable physical discomforts or risks involved. If there are questions that are too sensitive for you to answer, you do not need to answer them.

POSSIBLE BENEFITS OF THIS STUDY This study may help you learn more about your own dairy intake and how to incorporate dairy into your diet.

ETHICS APPROVAL This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4–59, telephone numbers (012) 356 3084/(012) 356 3085 and written approval has been granted by that committee (Protocol number 705/2018). The study has been structured in accordance with the Declaration of Helsinki (last updated October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the declaration may be obtained here should you wish to review it.

INFORMATION If you have any questions concerning this study, you may contact Monique Piderit: 072 381 5282/s28020945@tuks.co.za.

CONFIDENTIALITY All records from this study will be regarded as confidential. All results will be published or presented in such a way that it is not possible to identify you as a participant. Information gathered in this study is for research purposes only and will not be used for marketing purposes. You will indicate your participant code in the completion of the Dairy Diary. The researcher will keep a list of these participant codes and your student number in the event that you forget your participant code.

COMPENSATION You will not be paid to take part in the study.

CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have received, read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I am aware that information shared in this study is for research purposes only and will not be used for marketing purposes.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and my withdrawal will not affect my employment or student status.
- I am participating willingly. I have received a copy of this informed consent agreement, on request.

To continue, please indicate YES or NO, and then select the blue arrow on the bottom right of the page.

INSTRUCTIONS FOR THE THREE-DAY WEIGHED FOOD RECORD

Instructions

1. Keep this food diary for three days. Choose two weekdays and one weekend day. Ensure that the days you record are not consecutive (i.e. not one after the other).

2. Please record everything that you consume (e.g. food, water, drinks, and supplements) in a full 24-hour period.

3. Using the provided template, list all foods/drinks immediately as eaten.

4. Record only the food eaten, e.g. leftovers and non-edible parts such as bones or the core of apple must be indicated (weigh the food when dishing up, then weigh amount left).

5. Remember to record all components of a meal/eating occasion (e.g. sauces, dressing, margarine, and oil used in cooking).

6. Record only one food item per line on the provided template.

7. Describe foods in detail (e.g. brand names, raw/cooked, and how it was prepared).

8. Record the amount using the scales provided and food labels to assist you.

9. Hand in the wrappers of any food products if they contain nutritional information.

10. For tinned food, include the liquid it is canned in (e.g. tuna in brine or fruit in syrup). Specify how much of each was eaten.

11. For composite dishes (e.g. mixed vegetables or cottage pie) give components or recipes and indicate proportions you have eaten (e.g. split the minced meat and the mashed potato).

12. Do not change your normal diet when completing the three-day food record.

Example of How to Keep the Food Record

Time and place/ occasion	Food or drink consumed	How much? (units)	Details: preparation method/comments
8:00 Breakfast Home kitchen	All Bran Flakes	100 g	Kellogg's
	Raisins	20 g	Added extra
	Milk	125 mL	Full cream (Clover)
	Coffee	270 mL	Nescafe instant
	Milk, 2%	30 mL	Clover
	Sugar	10 mL	White
	Rusk	50 g	Ouma buttermilk rusks
10:00am Snack, campus	Chocolate	56 g	Bar One
11:00am Snack, campus	Fruit juice	250 mL, tetrapack	Liquifruit, mango and orange
	Bread roll	70 g	White, Portuguese
	Spread (on both halves)	12 g	Medium-fat margarine (Flora)
	Cheese	2 wedges: 2 × 26 g = 52 g	(Melrose) regular, biltong flavour
	Tomato	50 g	Fresh, sliced
	Olives	3 (without stones, in brine) = 8 g	Black (Kalamata)
	Lettuce	20 g	Fresh, iceberg
	Salad dressing	10 g	Knorr, blue cheese, low fat
12:00 Movies	Popcorn	100 g	Cooked (popped) in oil, with salt and vinegar
	Coke, diet	1 tin 340 mL	
etc.			

Standardised Template for Weighed Three-day Food Record

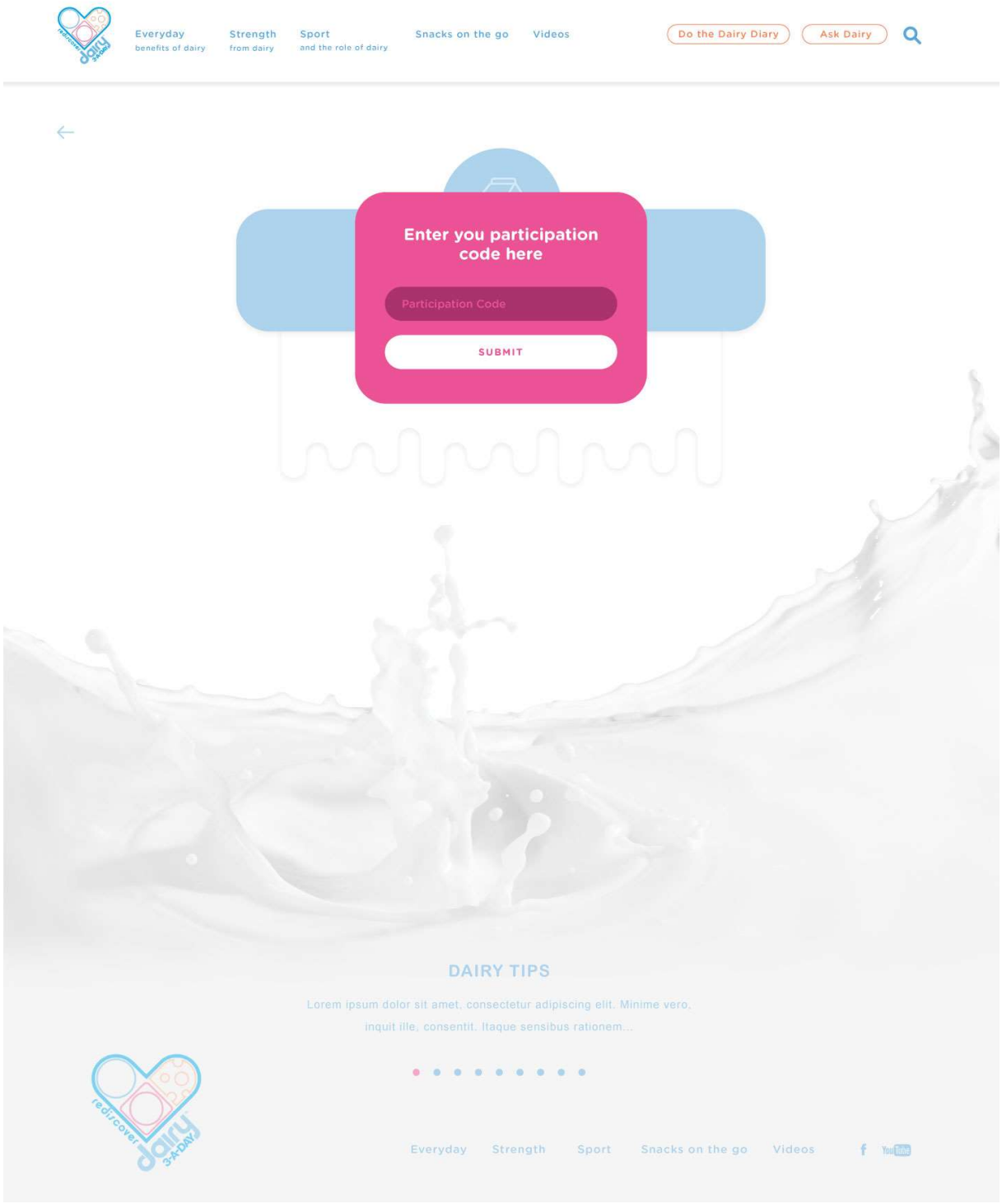
Participant code								
Date of recording	Y	Y	Y	Y	M	M	D	D
Day of week on which record was kept	Mon 1	Tue 2	Wed 3	Thu 4	Fri 5	Sat 6	Sun 7	

Time and place	**Food or drink consumed**	**Amount (units)**	**Preparation method/ comments**
Was this a typical intake for this day of the week? Circle		Yes No	

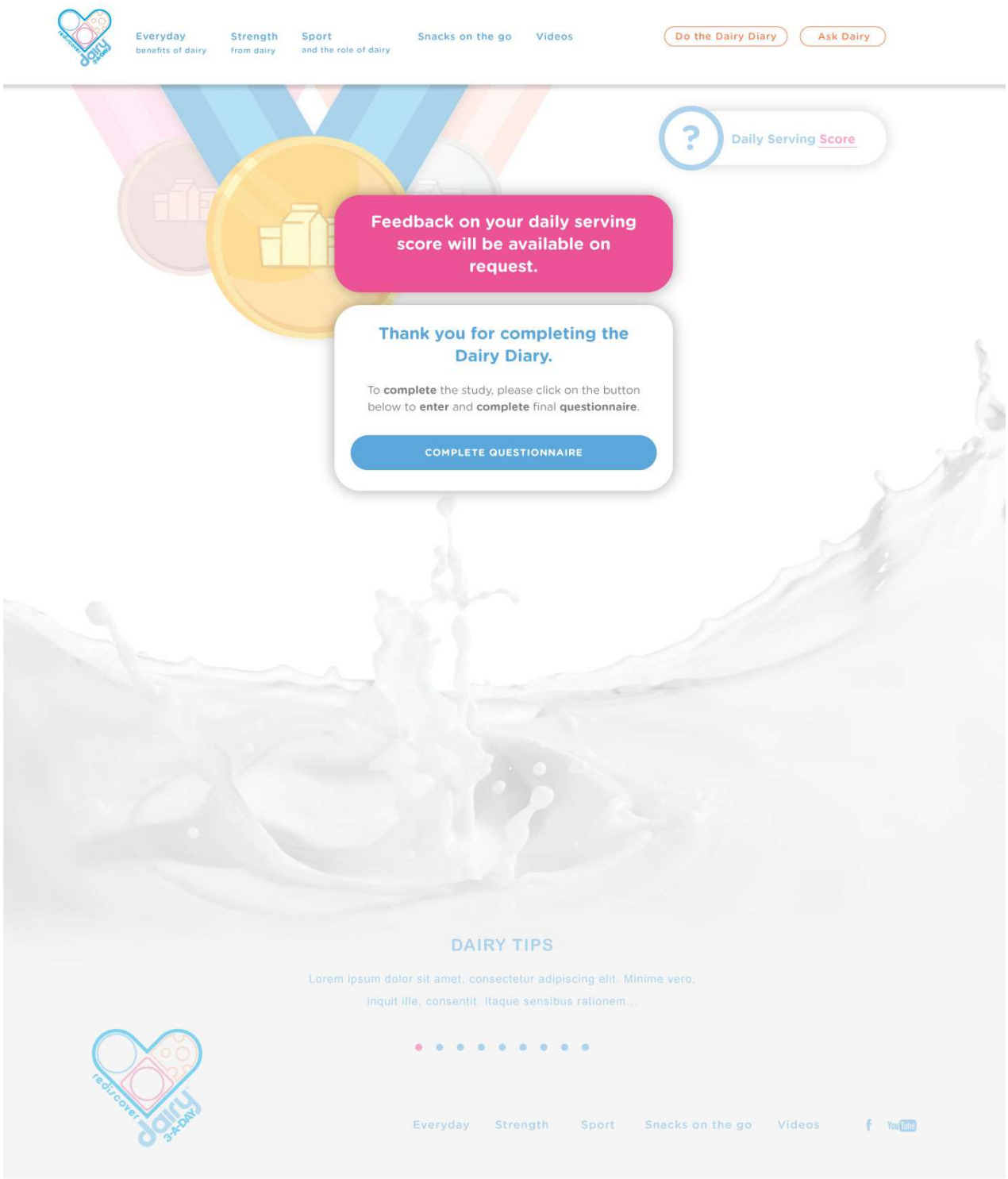
Coding Assumptions for Data Capturing and Data Management of the Three-day Weighed Food Records

Food Item	Assumption
Drinks – Cold	
Iced coffee frappe (125 ml)	100 ml milk
Breakfast smoothie	½ cup = 120 g
Iced coffee (300 ml)	200 ml
Drinks – Hot	
Cappuccino, instant sachet (Nescafe Gold)	19% skim milk powder = 2.4 g milk per sachet
Cappuccino (250 ml)	200 ml milk as per Illy website
Cappuccino (200 ml)	125 ml milk as per Illy website
Hot chocolate (250 ml)	125 ml milk
Rooibos tea, with milk	50 ml milk
Instant coffee, with milk	50 ml milk
Chai latte	200 ml milk
Café mocha	125 ml milk
Frozen Foods	
Frozen yoghurt	As per portion indicated
Ice cream	Not included as dairy
Cheese	
Cheese sauce, Royco	Negligible
Mozzarella cheese, in salad	10 g
Feta cheese, in Greek salad	30 g
Parmesan cheese, sprinkled on pasta	5 g
Composite Dishes	
Pizza, margarita	30 g cheese
Macaroni and cheese	30 g cheese
Bobotie	42 ml milk
Lasagne, homemade	30 g cheese

Graphics of the Dairy Diary as Seen in the Validity Study




Everyday
benefits of dairy
Strength
from dairy
Sport
and the role of dairy
Snacks on the go
Videos
Do the Dairy Diary
Ask Dairy
BRONZ
0 - 1
GOLD
2 - 3
SERVINGS
ILVER
1 - 2
2.44
Daily Serving Score
You need 3 servings of dairy a day
40%
Milk
15%
Maas
29%
Yoghurt
16%
Cheese
Did you enjoy doing the Dairy Diary?
Stand a chance to win one of three R1000 online vouchers to a retailer of choice. Click on the button to take part in a research survey.
ENTER RESEARCH SURVEY
WELL DONE!
Your dairy intake meets recommendations!
Try some dairy recipes to keep this up.
View Recipes
Ask Dairy
Try some dairy recipes to keep this up.
View Recipes
Ask Dairy
Try some dairy recipes to keep this up.
View Recipes
Ask Dairy
DAIRY TIPS
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Minime vero, inquit ille, consentit. Itaque sensibus rationem...
Everyday
Strength
Sport
Snacks on the go
Videos


Everyday
benefits of dairy
Strength
from dairy
Sport
and the role of dairy
Snacks on the go
Videos
Do the Dairy Diary
Ask Dairy
Daily Serving Score
Feedback on your daily serving score will be available on request.
Thank you for completing the Dairy Diary.
To complete the study, please click on the button below to enter and complete final questionnaire.
COMPLETE QUESTIONNAIRE
DAIRY TIPS
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Minime vero, inquit ille, consentit. Itaque sensibus rationem...
Everyday
Strength
Sport
Snacks on the go
Videos

ANNEXURE F: ACADEMIC POSTER PRESENTATIONS

Academic Poster Presented at Nutrition Congress 2018

Academic Poster Presented at International Congress of Dietetics 2021

Development and Evaluation of a Web-Based Mobile Application as a Dairy Intake Screener for South African Adults

BACKGROUND/AIM

Traditional dietary assessment tools are making way for **technology-based** versions. Amidst low dairy intakes in South Africa, we aimed to develop an application (app) intended to **screen dairy intake** and **evaluate its usability**.

METHODS

Informed by public and private interests and scientific Best Practice Guidelines, a dairy intake screener ("**Dairy Diary**") was developed as a **web-based mobile app** for higher income South African adults.

Using the end-user version of the Mobile Application Rating Scale (uMARS), online recruitment of a convenience sample of 1 102 participants evaluated the "Dairy Diary" in April 2020 via a link to a **digital questionnaire** (Qualtrics). Participants with incomplete and/or missing data (n=354), those with living standards measure < 8 (n=37), and those who did not give consent (n=8) were excluded from the study. The final sample included 703 participants (81% female).

RESULTS

The "Dairy Diary" resulted in an eight-item **quantitative food frequency questionnaire**, including forms of commonly consumed local dairy products: **milk**, **maas** (fermented milk), **yoghurt**, and **cheese** (hard and soft). Reported frequency of consumption and portion size were scored, resulting in three risk classes. Digitalisation included graphics and a link to relevant preliminary guidance. The app objective quality mean score (3.9±0.85), app subjective quality score (3.5±0.77), and app-specific mean score (3.6±0.94) each met the minimum acceptability score of ≥ 3.0 (score range 1.0 – 5.0). For the subscales, the mean score for aesthetics was the highest (4.4±0.82), followed by information (4.3±0.90) and functionality (4.0±1.33). Engagement scored lowest (3.0±1.55).

CONCLUSION

The "Dairy Diary" is a user-friendly screener for dairy intake.

SCALES and SUB-SCALES		ITEM	MEAN [a]	SD [b]
App Quality (Objective)			***3.1***	***0.85***
Engagement	1.	Entertainment	3.2	1.38
	2.	Interest	3.5	1.43
	3.	Customisation	2.0	1.71
	4.	Interactivity	2.5	1.69
	5.	Target group	3.9	1.54
		Mean	*3.0*	*1.55*
Functionality	6.	Performance	4.0	1.54
	7.	Ease of use	4.1	1.36
	8.	Navigation	3.8	1.45
	9.	Gestural design	3.9	1.86
		Mean	*4.0*	*1.33*
Aesthetics	10.	Layout	4.5	0.95
	11.	Graphics	4.3	1.00
	12.	Visual appeal	4.3	0.89
		Mean	*4.4*	*0.82*
Information	13.	Quality of info	4.3	0.97
	14.	Quantity of info	4.2	1.17
	15.	Visual info	4.4	1.05
	16.	Credibility of source	4.2	1.19
		Mean	*4.3*	*0.90*
App Quality (Subjective)			***3.5***	***0.77***
Subjective Quality	17.	Recommend the app	3.7	1.24
	18.	App use in one year	4.3	1.31
	19.	Pay for app	2.3	0.99
	20.	Overall star rating	3.7	0.72
App-Specific			***3.6***	***0.94***
App-Specific	21.	Awareness	3.8	1.05
	22.	Knowledge	3.8	1.05
	23.	Attitudes	3.5	1.11
	24.	Intention to change	3.4	1.14
	25.	Help seeking	3.5	1.18
	26.	Behaviour change	3.3	1.19

a: Score range from 1 – 5 ; b: standard deviation

TABLE 1: THE uMARS SCALE, SUB-SCALES AND ITEMS: MEAN AND TOTAL SCORE FOR THE SAMPLE (N=703)

dairygivesyougo.co.za/dairy-diary

Acknowledgement:
Consumer Education Project of Milk SA
www.rediscoverdairy.co.za

Monique C Piderit, Zelda White, Friede AM Wenhold
Department Human Nutrition, Faculty of Health Sciences,
University of Pretoria, South Africa 2021

The study was approved by the University of Pretoria, Faculty of Health Sciences Research Ethics Committee (Certificate: 705/2018)

Academic Poster Presented at University of Pretoria Faculty Research Day 2022

The usability of a web-based mobile application as a DAIRY INTAKE SCREENER for South African adults

Monique C Piderit, Zelda White, Friedeburg AM Wenhold
Department of Human Nutrition, Faculty of Health Sciences, University of Pretoria, South Africa

BACKGROUND

Paper-based dietary assessment and screening tools are making way for versions that use technology. Amidst low dairy intakes in South Africa, and to increase public awareness thereof, the "Dairy Diary" screener was developed as a web-based mobile application (app) in the form of an eight-item quantitative food frequency questionnaire focusing on four dairy products commonly consumed in South Africa: milk, maas (fermented milk), yoghurt, and cheese. The aim of this study was to evaluate the usability of the "Dairy Diary."

METHODS

The "Dairy Diary" was evaluated in an online cross-sectional survey (Qualtrics; April 2020) with the user version of the 26-question Mobile Application Rating Scale (uMARS) and an additional question on e-portion. Questions were scored on a 5-point Likert-type scale and combined into three scores and four sub-scales. From a conveniently recruited sample of 1102 adults, 703 (64%; 81% female; mean age 29.8±11.0 years) met the inclusion criteria and were retained for analysis. uMARS-informed descriptive statistics and interpretation guidelines summarise the findings.

RESULTS

The uMARS app mean scale and sub-scale scores all met the minimum acceptability score of ≥ 3.0. For the subscales, the mean score for aesthetics was the highest (4.4±0.82).

TABLE 1: THE uMARS SCALE, SUB-SCALES AND ITEMS: MEAN AND TOTAL SCORE FOR THE SAMPLE (N=703)

SCALES and SUB-SCALES	ITEM	MEAN SCORE	SD
App Objective Quality: Total Score		**3.9**	**0.85**
Engagement	1. Entertainment	3.2	1.38
	2. Interest	3.5	1.43
	3. Customisation	2.1	1.71
	4. Interactivity	2.5	1.69
	5. Target group	3.9	1.54
	Mean	3.0	1.55
Functionality	6. Performance	4.0	1.54
	7. Ease of use	4.1	1.36
	8. Navigation	3.8	1.45
	9. Gestural design	3.6	1.86
	Mean	4.0	1.33
Aesthetics	10. Layout	4.5	0.95
	11. Graphics	4.3	1.00
	12. Visual appeal	4.3	0.89
	Mean	4.4	0.82
Information	13. Quality of info	4.3	0.97
	14. Quantity of info	4.2	1.17
	15. Visual info	4.4	1.05
	16. Credibility of source	4.2	1.19
	Mean	4.3	0.90
App Subjective Quality: Total Score		**3.5**	**0.77**
Subjective quality	17. Recommend the app	3.7	1.24
	18. App use in one year	4.3	1.31
	19. Pay for app	2.3	0.99
	20. Overall star rating	3.7	0.72
App-Specific: Total Score		**3.6**	**0.94**
App-Specific	21. Awareness	3.8	1.05
	22. Knowledge	3.8	1.05
	23. Attitudes	3.5	1.11
	24. Intention to change	3.4	1.14
	25. Help seeking	3.5	1.18
	26. Behaviour change	3.3	1.19

CONCLUSION

The "Dairy Diary" is a user-friendly screener for dairy intake and should be validated.

Do the Dairy Diary on **www.dairygivesyougo.co.za/dairy-diary/**

2022

Faculty of Health Sciences

Academic Poster Presented at University of Pretoria Faculty Research Day 2023

ANNEXURE G: TURNITIN REPORT

Thesis - Monique C Piderit - Final with Ref - 20230823 -For Turnitin v2.docx

ORIGINALITY REPORT

16%	14%	17%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	repository.up.ac.za Internet Source	4%
2	Sharon I. Kirkpatrick, Tom Baranowski, Amy F. Subar, Janet A. Tooze, Edward A. Frongillo. "Best Practices for Conducting and Interpreting Studies to Validate Self-Report Dietary Assessment Methods", Journal of the Academy of Nutrition and Dietetics, 2019 Publication	2%
3	Submitted to University of Pretoria Student Paper	2%
4	ada.portalxm.com Internet Source	1%
5	J. E. Cade. "Food-frequency questionnaires: a review of their design, validation and utilisation", Nutrition Research Reviews, 06/2004 Publication	1%

ANNEXURE H: DECLARATION OF LANGUAGE EDITING

In a Word

Marike van Rensburg
Copy-editor
082 820-4716

Po Box 11823
Wierdapark South
0157
marike.vanrensburg@gmail.com
www.inaword.co.za

Monique Cruz Piderit
University of Pretoria
Student number: 28020945

14 August 2023

Copy-editing certificate

This document serves to confirm that the following thesis was copy-edited:

Usability and validity of a dairy intake screener as a web-based mobile application for South African adults

Copy-editing included:

- Checking language in terms of spelling, grammar and punctuation.
- Checking consistency of terminology and style.
- Checking the style of references and citations against the provided style guide (accuracy and completeness of source information remain the responsibility of the student).

The Microsoft Word® track changes functionality was used to make the student aware of changes. It is the student's prerogative to choose whether to accept or reject suggested changes.

The document remains the original work of the student. The copy-editor has not added any additional information, rewritten sections, or changed the structure of the document.

Sincerely,

Marike van Rensburg

in a word