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Get active now or later? The association between physical activity and risk and time preferences

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ABSTRACT

Despite the well-established link between physical activity and positive health outcomes, much of the world's population remains inactive. Many people don't invest in health behaviours, such as physical activity, in the present, despite the long-term benefits of this. The aim of this study was to assess the relationship between physical activity levels and risk and time preferences in university students. A maximum likelihood model was used to jointly estimate risk and time preferences (elicited in an incentivised choice experiment), and to examine the relationship between these preferences and self-reported physical activity. Physically inactive people discounted the future significantly more than physically active people did. Physically active people made slightly more risky choices in our risk attitude task, although this directional relationship was not statistically significant. The link between time preferences and physical activity suggests that further research on behavioural strategies such as commitment devices, nudging or temptation bundling may be helpful in increasing physical activity for individuals who discount the future in favour of more immediate benefits.

1. Introduction

There is a well-established link between regular physical activity and positive health outcomes, such as the prevention of non-communicable diseases and premature death (Warburton et al., 2006; Lee *et al.*, 2012; Lear *et al.*, 2017; Zhao et al., 2020; Lambert & Bull, 2023). Despite the strong evidence for the role of physical activity in disease prevention, more than a quarter of the global population remains inactive (Kohl et al., 2012; Guthold, Stevens, Riley, & Bull, 2018; Nikitara et al., 2021). Prevalence rates have remained largely unchanged in the last two decades and have almost doubled in high income countries (Guthold, Stevens, Riley, & Bull, 2018), whilst the economic burden of this modifiable risk factor continues to escalate (Ding et al., 2016; Lee *et al.*, 2012).

Changing health-related behaviours, and in particular physical activity, is a complex and multifaceted issue, which is influenced by a variety of factors (Bauman et al., 2012; Rutter et al., 2019). Much of the physical activity literature has focused on psychological and biological influencing factors, such as perceived competence, self-efficacy, attitudes as well as environmental factors (Bauman et al., 2012). However, since being physically active involves decisions about time allocation, energy costs and other trade offs, behavioural economic principles of preferences and risk attitudes may provide an important method of studying such health behaviours.

The concept of health can be viewed as a form of human capital, into which investments are made now, for future gain (Grossman, 1972). However, the current rates of physical inactivity worldwide (Guthold, Stevens, Riley, & Bull, 2018) would suggest that people do not have the beliefs or preferences that would prompt them to invest time or resources into being active today to gain health benefits in the future. This is likely related to issues of present-bias such as self-control problems, procrastination, or short-term-self versus long-term-self problems (Hunter *et al.*, 2018). Additionally, physical activity requires effort and energy expenditure, which unlike other health behaviours (vaccinations, taking medications etc.), can further decrease the perceived value of the reward (effort discounting) (Iodice et al., 2017; Klein-Flügge et al., 2015).

This idea of the value of a reward (in this case, health, and longevity) being discounted when there is a delay to receiving the reward is related to time preferences. Time preference measures are often decomposed into a measure of present bias (where present costs/benefits are weighted more highly than future costs/benefits) and discount rate (the

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rate at which future costs/benefits are discounted or underweighted as the time period between the decision and the point at which costs/benefits will be incurred/enjoyed by the individual increases) (Laibson, 1997; Loewenstein & Prelec, 1992). There is a growing body of recent research around time preferences and health behaviours (Conell-Price & Jamison, 2015; Lawless, Drichoutis, & Nayga, 2013). For example, time preferences have been linked to body mass index (Smith et al., 2005) and diabetes onset and management (Mørkbak et al., 2017). Bradford (2010) found that high discount rates were negatively associated with preventative health screening, dental visits, cholesterol screening and vigorous physical activity levels. More closely related to our work, Kosteas (2015) found that time preference was a significant predictor of vigorous physical activity in men and women as well as light-to-moderate physical activity in women. Similarly, Hunter *et al.,* (2018) found that those who were present-biased were significantly less active. They found a 3 % lower discount rate and a 1.14 unit decrease in present-bias was associated with a 30-min increase in physical activity per week. Furthermore, those with strongly future-oriented time preferences are 1.2 times more likely to meet the recommended physical activity guidelines (Shuval et al., 2017). This suggests that small shifts in time preferences may have significant impacts on physical activity levels.

Another important aspect of understanding and predicting behaviour is an individual's attitude towards risk (Dohmen et al., 2011). Risk attitudes are known to influence decision making under uncertainty. In health economics, risk attitudes would be expected to influence the purchase of health insurance, as well as preventative behaviour and decisions to engage in activities that might impact mortality risk (Anderson & Mellor, 2008). Previous studies have shown that being risk averse is negatively associated with many risky health behaviours such as smoking, heavy drinking, being overweight (Barsky et al., 1997), as well as unhealthy diets (Galizzi & Miraldo, 2017). Since physical inactivity has been identified as the fourth leading cause of death worldwide (WHO, 2009), one may argue that physical inactivity is a risky behaviour. However, there is little research to date regarding the influence of risk attitude on physical activity levels. Results from a study measuring compliance with physician advice to change physical activity levels, showed that risk attitude does not seem to be associated with compliance (Van der Pol et al., 2017). On the other hand, Leonard et al. (2013), found that individuals who were more tolerant of financial risk appeared to be at an advanced stage of readiness to change their physical activity behaviours.

Much of the physical activity related literature to date has measured time preferences using non-incentivised or hypothetical questions (Conell-Price & Jamison, 2015; Kosteas, 2015; Shuval et al., 2017) or did not include risk attitudes (Leonard et al., 2013). The importance of eliciting both risk and time preferences so that time preferences can be disentangled from risk attitudes is widely acknowledged (Andersen *et al.* 2008). Furthermore, none of the existing studies jointly estimated risk and time preferences, which is recommended. Therefore, the aim of this study is to investigate the relationship between risk and time preferences and physical activity levels, using a maximum likelihood model.

2. Methods

2.1. Study design and participants

We conducted a laboratory experiment with undergraduate economics students from a South African university. Undergraduate economics students were invited to participate in a "Decision Making experiment" on 24 October 2018. This sample was chosen for several reasons. Firstly, since there may be age-related differences in risk attitudes (Rolison, Hanoch, Wood, & Liu, 2014; König, 2021) and possibly time preferences (Read & Read, 2004; Seaman et al., 2022), university students present a relatively homogenous age group. Secondly, although physical activity has been seen to decline when starting university (Memon et al., 2021; Castro et al., 2020), this age group is not hindered by physical deterioration, chronic health issues and family time constraints found in their older counterparts. Lastly, economics at this university is a required undergraduate module in a wide range of courses (e.g. law, agriculture, statistics etc.) and therefore this sample encompassed students from a variety of educational backgrounds with less obvious bias than if we had included exercise science students.

Interested students signed up online for a session time that suited their academic timetable. Participants arrived at the designated computer lab and were seated at prepared computer terminals, where they first signed an informed consent document, then responded to a series of choice questions (detailed in the tasks that follow) online. All answers were anonymous (participants were asked to use an "alias" when they started the online session so that their actual responses could be retrieved at the end of the experiment for incentive compatible payment, while still retaining anonymity). Sixty-nine participants attended one of the 3 sessions, which lasted between 45 and 60 min.

We used an incentive compatible experiment design for eliciting both risk and time preferences. Preferences were elicited using a series of pairwise choice questions over monetary lotteries where the probabilities of different payment amounts varied (risk attitudes) or between an earlier and a later payment where the delay leading up to the earlier payment, the gap between payments and the interest rate varied (time preferences). The widely used Random Lottery Incentive Mechanism was used for incentive payments, whereby respondents would randomly select (by rolling 10-sided dice) one question to be played for payment. Respondents were advised at the start of the experiment that their best approach was to make each choice as if it was the one to be paid in real money, such that, should that choice be paid, they would be satisfied with the outcome. Participants were paid a show-up fee of ZAR20 in addition to the variable payment based on the choice selected for payment and their decision in the experiment. Total payments ranged from ZAR50 to ZAR200, with an average payment of ZAR121.97 (For reference, the hourly rate for student assistants working in the University's Economics department at the time of the experiment was ZAR85).

Where risk attitude tasks were randomly selected for payment, payments were made in cash immediately after the experiment. Where time preference tasks were randomly selected, the payment mechanism varied: for smaller sooner payments with no front-end delay, payments were made in cash. If the larger later payment was chosen, or if there was a front-end delay, participants had the option of an online bank transfer (for which they could provide bank details immediately or by email) or a cash payment (which they could collect from the Economics department) on the date specified in the chosen option.

2.2. Measures/data collection

2.2.1. Risk attitudes

Risk attitudes were measured using a series of questions compiled by Wilcox (2018). Wilcox's question series has been used in recent research (Hofmeyr et al., 2023; Wilcox, 2023) and is designed specifically to improve upon existing risk attitude measurement tasks in its ability to distinguish between utility function curvature and probability weighting by being able to accurately estimate 2 utility parameters. Since these aspects of risk attitudes have different cognitive foundations, and different behavioural implications, the ability to accurately estimate both will improve our ability to understand risk attitudes and their interaction with time preferences and physical activity. Respondents make a total of 100 choices between paired lotteries, where each lottery is represented by a roll of a 6-sided die (Wilcox selected the 6-sided die as a familiar chance device that would cover a relevant range of probabilities), with different outcomes associated with different die facings. In each question there is a safe and risky option, whereby the risky option involves a (higher) possibility of a greater payment and a (higher) possibility of a smaller payment. In total there are 4 possible payment amounts: ZAR30, ZAR60, ZAR75 and ZAR180, and each choice question has varying probabilities over 3 of these 4 amounts. That is, choice pairs cover a range of 3-outcome Marschak-Machina triangles, set up such that pairs are rich enough to allow interesting risk trade-offs, but not more complex than necessary to measure risk attitudes. As a concrete example, one of the choices was between a ZAR60 payment for any number from 1 to 6 rolled (the "safe" option); and a ZAR30 payment for dice rolls 1–5, and a ZAR180 payment if a 6 is rolled (the "risky" option). In some cases, the expected value is higher for the safe option, while in other cases it is higher for the risky option, and in still others, the expected value is identical.

2.2.2. Time preferences

Following Coller and Williams (1999) and Harrison et al. (2018), we measured time preferences using a series of choices between smaller, sooner (SS) and larger, later (LL) payments. In all cases, the principal (SS) reward was R100, with the larger, later reward varying. The time horizon between the SS and LL payment varied, as did the nominal annual interest rate used in calculating the LL payment. We also included both immediate SS payments and SS payments with a front-end delay of 1 week. Including payment questions with a front-end delay allows us to hold any subjective transaction costs associated with delayed payments constant between the SS and LL options. Further, the 0-day front end delay allows us to estimate a "present bias" parameter (β), while the positive front end delay allows for estimation of the long-term discounting parameter (δ), as in Laibson's (1997) seminal model of time preferences.

In total our respondents answered 30 time preference questions including 2 front end delays (0 days and 1 week); 3 time horizons between SS and LL (1 week, 2 weeks and 3 weeks) and 5 nominal annual interest rates (10 %, 25 %, 50 %, 100 % and 200 %). We followed Harrison *et al.* (2018) in sequentially presenting batches of questions with varying interest rates for the LL payment for each front-end delay and time horizon combination.

2.2.3. Physical activity levels

The World Health Organization's recommended physical activity levels for adults aged 18–64 is 150 min of moderate-intensity physical activity per week, 75 min of vigorous physical activity or a combination of the two (Bull et al., 2020). Accordingly, we used a single-item question to measure physical activity levels: "In the past week, on how many days have you done a total of 30 min or more of physical activity, which was enough to raise your breathing rate. This may include sport, exercise, and brisk walking or cycling for recreation or to get to and from places but should not include housework or physical activity that may be part of your job." (Milton *et al.*, 2011). This question is tailored to the current physical activity guidelines and has demonstrated strong repeatability and moderate validity (Milton et al., 2011). It allowed us to define active individuals as those who had completed 30 min or more of activity at least 5 times in the past week (Milton, Clemes, & Bull, 2013; O'Halloran et al., 2020).

Participants also filled out a self-report health rating on a scale of 1–10, with 1 indicating very bad health and 10 indicating excellent health, as well as questions on weekly alcohol consumption and smoking.

The study was approved by the University of Pretoria's Faculty of Economic and Management Sciences Research Ethics Committee (Ref: EMS130/18).

2.2.4. Statistical analysis

Data were analysed using a full information maximum likelihood statistical framework in Stata. As in Andersen *et al.* (2008) and Harrison *et al.* (2018), we estimate risk attitudes and time preferences as a linear function of observable characteristics (including whether an individual was physically active or not as well as other demographic variables). Specifically, we use models of risk and time preferences to capture latent choice processes, where the model coefficients are estimated using maximum likelihood techniques. Details of the model specification are given in the supplementary files.

For risk preferences, we estimate risk aversion through an *r* parameter in a constant relative risk aversion (CRRA) utility function, where higher values of *r* indicate more risk averse decision making, and negative values indicate risk seeking decision making. We incorporate probability optimism/pessimism in the utility function using a γ parameter in a power probability weighting function, where values less than 1 indicate optimism and values greater than 1 indicate pessimism. We initially estimated two models of time preferences, a standard model with exponential discounting, as well as Laibson's (1997) model, where present bias is estimated separately from the discount factor, distinguishing between bias towards today (the present) and bias towards earlier rather than later rewards. Since including the present-bias β-parameter in the Laibson model gave us an estimate of $\beta = 1$, showing no evidence of present bias in our data, we report the exponential discounting model. In the reported model, the δ parameter indicates the extent to which later/future costs or benefits are discounted relative to costs or benefits incurred earlier. A δ value of 1 indicates no discounting of future costs or benefits, while values less than 1 indicate that later benefits are discounted relative to earlier benefits.

3. Results

3.1. Summary statistics

Table 1 shows descriptive statistics for our sample of 69 undergraduate economics students.

Physically active individuals report statistically significantly better overall health than those who are less physically active (Table 2). Physically active individuals tended to make more patient (LL) choices on the time preference task than those who are less physically active, but make fewer safe choices on the risk attitude task. However, neither of these differences was statistically significant.

Table 3 shows the results of the maximum likelihood estimate. This is a method of estimating the parameters of assumed probability distribution (Myung, 2003), where we examine the link between physical activity and risk and time preferences in a more robust way. In this model, we estimate 3 main parameters: *r* measures risk aversion (where higher values are associated with greater risk aversion); γ measures probability optimism/pessimism, (where values less than 1 indicate optimism, while values greater than 1 indicate pessimism). Finally, δ is a discounting parameter, where lower values indicate more discounting of the future (greater impatience). Table 3 indicates the association of higher physical activity levels (*Active*), as well as demographic variables,

Table 1
Descriptive statistics.

Demographics	n	Mean ± SD or n (%)
Age (years)	69	20.62 (±1.67)
Gender	69	
Female		36 (52 %)
Male		33 (48 %)
Race	69	
Black		45 (65 %)
White		18 (26 %)
Other		6 (9 %)
Physical activity levels	69	
Active		21 (30 %)
Inactive		48 (70 %
Number of physically active days	69	3.07 (±2.28)
Smoking status	69	
Smoker		15 (22 %)
Non-smoker		54 (78 %)
Alcohol (units/week)	69	2.41 (±5.06)
Health rating score (/10)	69	7.75 (±1.56)
Time preferences (no. patient choices/30)	69	7.74 (±8.04)
Risk preferences (no. safe choices/99)	69	40.97 (±14.32

Table 2
Comparison of health outcomes and preferences between active and less active participants.

	Active (n = 21)	Less active (n = 48)	p-value[a]
Health rating score (/10)	8.43 (±1.36)	7.46 (±1.56)	p < 0.01[b]
Risk preference (no. safe choices/99)	36.38 (±16.99)	42.98 (±12.66)	p = 0.22
Time preferences (no. patient choices/30)	9.86 (±8.77)	6.81 (±7.61)	p = 0.18

[a] Wilcoxon rank-sum test
[b] Indicates statistical significance

Table 3
Maximum likelihood estimates (probit model).

	Estimate	Std Error
CRRA utility parameter (r)		
Active	−0.10	0.070
Female	0.039	0.038
White	−0.010	0.0092
Alcohol units/week	−0.00067	0.0010
Health rating	−0.014	0.013
Non-smoker	0.035	0.031
Constant	1.20[c]	0.092
Power PWF parameter (γ)		
Active	−0.13	0.12
Female	−0.043	0.13
White	−0.15	0.14
Alcohol units/week	−0.0060	0.0078
Health rating	0.020	0.033
Non-smoker	0.044	0.18
Constant	0.85[b]	0.38
Discounting parameter (δ)		
Active	0.17[a]	0.095
Female	−0.030	0.034
White	0.0081	0.0086
Alcohol units/week	0.00032	0.00048
Health rating	0.0098	0.010
Non-smoker	−0.056	0.048
Constant	0.78[b]	0.094
Error terms		
Risk error	0.219	0.014
Time error	0.0285	0.0056
N	8769	
Log likelihood	−4537.894	

Results account for clustering at the individual level.
[a] $p < 0.1$;
[b] $p < 0.05$;
[c] $p < 0.01$

with each of these estimated parameters.

Our data show high levels of aggregate risk aversion in the concavity of the utility function ($r > 1$). There is some evidence of optimism in the probability weighting function ($\gamma < 1$), which is offset by the high r, giving high aggregate levels of risk aversion overall. Although our physical activity measure does not show significant differences between those who are and are not physically active in terms of either possible measure of risk aversion, the direction of the results is in line with our findings from a count of the number of safe choices, that is, more physically active respondents show directionally lower risk aversion that those who are less physically active (for r, active respondents have a marginal coefficient of −0.10, meaning that for these respondents, $r = 1.1$). More active respondents are also more optimistic (for γ, active respondents have a marginal coefficient of −0.13, resulting in a γ for this group of 0.72).

There is some evidence of discounting of future payments in our sample. Those who are physically active have discount rates closer to 1 (adjusting for the marginal effect of being physically active: 0.17; $\delta = 0.95$ for physically active respondents, versus 0.78 for the reference group). Discount rates closer to 1 indicate less discounting of the future relative to the present. This finding is in line with the hypothesis that people who are more present-focused might be less willing to incur the cost of exercising in the present in order to reap the benefits of exercise, which generally fall in the future. Most of the individual demographic characteristics included have very small and non-significant associations with the parameters estimated. Interestingly, white respondents show somewhat greater optimism than other race groups, although this effect was not statistically significant.

4. Discussion

The results of this study showed that less physically active people (that is, people who exercise less than 5 days a week) discount the future more than physically active people do. There was no statistically significant difference in risk attitudes between physically active and inactive people in our sample, although physically active people were directionally less risk averse and more optimistic about probabilities than inactive people. We contribute to the literature on the impact of time preferences and risk attitudes on physical activity by using a full maximum likelihood model to jointly estimate time preferences and risk attitudes, where both risk aversion and probability optimism/pessimism are accounted for in the latter. Further, given the importance of paid incentives for accurate preference elicitation (Andersen *et al.*, 2008; Harrison *et al.*, 2005), we use an incentive compatible approach to eliciting these preferences. Much of the research on time preferences and physical activity to date has made use of hypothetical payments (Eberth *et al.*, 2020; Humphreys, Ruseski, & Zhou, 2015; Kosteas, 2015) to leverage larger samples. Our robust, incentive compatible estimate allows us to see whether the existing findings can be replicated. Contrary to Hunter *et al.* (2018), we do not find evidence of present bias in our sample. This difference might be related to accounting for probability optimism through our more complete utility function specification. Our model supports the existing research that physically inactive people discount the future more than physically active people do (Eberth *et al.*, 2020; Leonard *et al.*, 2013; Shuval et al., 2017). This finding points to the importance of accounting for these time preferences when designing and implementing programs aimed at increasing physical activity levels.

The challenge of getting inactive people moving has not been an easy one and has resulted in little global success (Hallal et al., 2012). Our results contribute to the growing evidence that economic preferences may play an important role in physical activity behaviour (Shuval et al., 2017), and interventions should be uniquely designed to accommodate for this. It may also, along with other determinants, explain why theories such as the social cognitive theory (SCT) has had limited success in changing physical activity behaviours. Although it is still the dominant research approach in physical activity, SCT is based on the premise that change in behaviours occur through deliberation of values and expected outcomes. However, there continues to be a large disconnect between population knowledge of the benefits of physical activity, and population prevalence of physical activity (Rhodes *et al.*, 2019). In other words, we may realise the benefits of being active, but our intentions don't match our behaviour due to issues of will power, self-control and self-regulation (Milkman et al., 2014).

Therefore, there is a need to develop new and innovative strategies. Being physically active involves a trade-off between short term costs such as time, effort, and energy expenditure versus long term health benefits. Behavioural science tools such as "nudging" (Thaler & Sunstein, 2021) encourage simplifying the decision-making process through altering people's choice architecture (Biddle & Mutrie, 2007). Small changes can make the healthy/active decisions easier, reducing the (cognitive) cost of deciding to engage in physical activity. However, despite the popularity of the nudging concept and the vast growth in physical activity research in the last few decades, there are surprisingly few studies looking at changing choice architecture to improve physical activity levels (Forberger et al., 2019). One emerging topic in the realm of behavioural economics and public health is around changing temporal perspectives. For example, if individuals are aware of their discounting, self-control and will power issues, short-term goal setting may be an effective solution (Swann et al., 2021). This can help to shorten the reward "delay" and emphasize the short-term benefits of physical activity such as enjoyment, improved mood or increased energy (Hunter et al., 2018). Adding to this, if these goals are framed with objectively equivalent "emergency rewards" it may help an individual's ability to persist even after failing to reach the goal (for example, reframing a goal of exercising 5 days a week to instead exercising 7 days a week with 2 emergency skip days). In getting participants to increase their daily step count, Sharif and Shu (2021) found that individuals with goals framed with emergency reserves are more likely to persist in the long term after a small failure, than those with goals framed without these reserves.

In line with this concept of framing (Tversky & Kahneman, 1981), simple, positive public health messages (such as the "Let's Move" campaign), position physical activity as a fun rather than an obligatory activity, thereby emphasising benefits in the present (Shuval, Leonard, et al., 2017). Another proposed strategy for overcoming time preference challenges is that of "Temptation Bundling" (Milkman *et al.*, 2014): linking contemporaneous rewards to physical activity (by, for example, listening to a particular podcast or watching a preferred Netflix series only while running on a treadmill or cycling on an exercise bike).

There is limited research focusing on risk attitudes and health, and even less looking at physical activity. We anticipated that a link between risk aversion and physical activity might exist where physical activity is believed to have preventive health benefits: our expectation was that physically active people might be more risk averse and might engage in physical activity in part to mitigate risks of adverse health effects of inactivity. We found no significant difference in risk attitudes between physically active and inactive people. Similarly, van der Pol et al. (2017) found that risk attitude was not associated with adherence to physical activity advice from a physician. Although not statistically significant, the differences that we noted were in the opposite direction to our hypothesis. Physically active people made slightly more risky choices in our risk attitude task; and our maximum likelihood model showed slightly lower risk aversion and more probability optimism among physically active people. This is similar to the findings of Leonard *et al.* (2013), who reported that risk seeking individuals were more likely to be active or preparing to be active (OR = 1.68, $p < 0.01$). Our study did not assess the types of physical activity undertaken and this may play a role in this association (for example, some sports such as contact sports may involve an element of increased risk).

Previous research has shown some contradictory findings with health and risk attitudes, with some studies reporting higher body mass index in risk averse individuals (Gao & Shen, 2017). It may be that cultural influences are at play (in some cultures a high BMI is perceived as a measure of wealth, as noted in Herberholz, 2020) or that risk attitudes may be domain specific (financial versus health versus social, discussed in Weber *et al.*, 2002 and Dohmen et al. (2011). Indeed, van der Pol and Ruggeri (2008) found that risk attitudes vary across different health outcomes, presenting evidence that, rather than being a stable personality trait, risk attitudes may be situation dependant. Further research would be needed to see whether the directional relationship noted in our data persists in other studies. If this is found to be the case, it might imply that physically inactive people perceive exercise as a risky behaviour and avoid it in part because of their aversion to risk. Related to this, perhaps people who are more optimistic in their probability weighting assign lower subjective probabilities to low probability adverse outcomes from physical activity, making these people more willing to overlook these risks and participate in physical activity.

The results of this study should be interpreted within the context of the study's limitations and strengths. Firstly, our study represents cross-sectional, single time-point data in a very specific population group. Physical activity patterns and behaviours tend to change over time and through different life stages, and an individual's investment in health may also change depending on age, health status and life stage (Chao et al., 2009; Eberth *et al.*, 2020). Further, our study did not investigate the intensity of physical activity (light versus vigorous). There appears to be an emerging association between time preference as a predictor of amount time spent in various physical activity intensities (Bradford, 2010; Hunter et al., 2018), and this may differ across genders (Kosteas, 2015). Indeed, since effort costs devalue the reward, the intensity of the activity may play a larger role in discounting and should be included in future studies (Klein-Flügge et al., 2015). Despite these limitations, our study is one of the few existing studies that look at the impact of time preferences as well as risk attitudes on physical activity. The importance of eliciting both risk and time preferences so that time preferences can be disentangled from risk attitudes is discussed at length in Andersen et al. (2008). While Hunter *et al.* (2018) used a similar approach to ours, their risk attitude estimate used a single parameter utility function, ignoring the role of probability weighting in risky decision making. A large body of literature in economics has pointed to the importance of accounting for probability weighting in predicting decision making under risk and uncertainty (Quiggin, 1982; Schmeidler, 1989; Tversky & Kahneman, 1992; Wakker & Tversky, 1993). Probability weighting incorporates the role of interpretation of probabilities: intuitively, a pessimistic decision maker faced with a coin flip where heads implies a win and tails implies a loss will overweight the likelihood of the loss, assuming that she is more likely to lose than to win, despite the objectively equal odds. An optimistic decision maker will overweight the likelihood of the win in the same gamble.

5. Conclusion

We used a maximum likelihood model to examine the relationship between risk attitudes and time preferences with physical activity. Our statistical approach allowed a more robust evaluation of existing findings of links between discounting of future costs and benefits and physical activity, by appropriately accounting for risk attitudes in our estimate of time preferences, and by using an incentive compatible study design. Although we do not find significant differences in risk attitudes between physically active and inactive people, we do note directionally less risk aversion in physically active people. Our findings confirm the dominant research finding that physically inactive people discount the future more than physically active people. This study emphasises the importance of using behavioural economic concepts, and accounting for these preferences in developing programs aimed at increasing population physical activity levels.

Disclosure statement

The authors report that there are no conflicting interests to declare.

Ethical approval

University of Pretoria Economic and Management Sciences Ethics Committee: EMS130/18.

CRediT authorship contribution statement

Nicky Nicholls: Writing – review & editing, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Estelle D. Watson:** Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

None

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2024.102650.

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