Poor cardiorespiratory fitness in first year medical students at a South African University

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ABSTRACT

The personal health behaviours, including physical activity, of healthcare professionals influence their counselling practices as they relate to non-communicable diseases (NCDs). However, despite the importance of producing healthy, physically active graduates, there are limited data on the physical fitness of future healthcare professionals. This cross-sectional observational study determined the prevalence of below-average fitness in the four components of fitness in first-year university medical students. 152 participants (46 male, 106 female, 20.16±2.69 years) completed cardiorespiratory fitness tests (submaximal step test), flexibility (sit-and-reach test), muscle strength (handgrip), and muscle endurance tests (sit-ups, push-ups). Sex differences were reported using one-way ANOVA or Chi square test and significance was set at $p<0.05$. The prevalence (%) of below-average fitness was 69.54% for cardiorespiratory, 25.66% for handgrip strength, 65.79% for sit-ups, 23.03% for push-ups and 7.24% for flexibility. Physical fitness parameters (mean±standard deviation (SD)) were compared between sexes, where it was found that females were more flexible than males (40.61±8.40cm vs 36.70±9.31cm, $p=0.012$). Males had better handgrip strength (88.96±12.04kg vs 59.34±10.36kg, $p<0.001$), muscle endurance sit-ups (33.46±9.04 vs 24.48±12.18, $p<0.001$) and push-ups (30.28±13.95 vs 24.27±12.35, $p=0.009$). First-year medical students have poor physical fitness, notably cardiorespiratory fitness and muscle strength, which are important markers for NCD risk assessment. Tertiary institutions training healthcare professionals should consider developing interventions to improve students' physical fitness thereby influencing their health, wellbeing, academic performance and future counselling practices.

KEYWORDS:

Health behaviour, physical activity, aerobic, strength, flexibility, college

INTRODUCTION

Non-communicable diseases (NCDs), including cardiovascular disease, cancers, chronic respiratory diseases and diabetes, are the leading causes of death and morbidity globally, being responsible for approximately 70% of all deaths (Beale and Demaio 2019; WHO 2014; Collaborators 2018). Physical inactivity, unhealthy diet, tobacco use and the harmful use of alcohol are accepted as being the most important modifiable behavioural contributors to the development of NCDs. Of these, physical inactivity is considered the most important risk factor (Beale and Demaio 2019; WHO 2014; Collaborators 2018). A body of evidence exists about the impact of the personal health behaviours of healthcare professionals on their counselling practices and, in turn, the health behaviour of their patients (Rogers et al. 2005; Pipe, Sorensen, and Reid 2009; Zhu, Norman, and While 2011; Bleich et al. 2012; Patra et al. 2015; Hidalgo et al. 2016; Hung, Keenan, and Fang 2013). For example, medical doctors that do not smoke, engage in regular physical activity, have good nutritional habits and a healthy body composition are more likely to prescribe lifestyle changes to their patients (Rogers et al. 2005; Pipe, Sorensen, and Reid 2009; Zhu, Norman, and While 2011; Bleich et al. 2012; Patra et al. 2015; Hidalgo et al. 2016; Hung, Keenan, and Fang 2013). While some evidence suggests that NCD risk factors such as low levels of physical activity are highly prevalent among medical doctors (Patra et al. 2015; Kasina, Ramella, and Paladugu 2015), there is a dearth of research in this area. It has been shown that medical students who engage in strenuous physical activity are more likely to perceive exercise counselling as being highly relevant to future clinical practice (Holtz et al. 2013). A more immediate benefit of a student having a physically active lifestyle is the positive relationship it has with academic performance (Deliens et al. 2013; El Ansari and Stock 2010). Research has also shown that lifestyle habits at a young age will determine health behaviours in later life (Cunnane 1993; Van Mechelen et al. 1999; Freedman et al. 2001), making this an important group to influence.

The importance of adopting a physically active lifestyle and the crucial contribution the healthcare professional can make in promoting this health behaviour highlights the need to understand the physical fitness of our future healthcare professionals. In previous research by this group a large proportion of 1st year medical students self-reported participating in low levels of habitual physical activity (Borresen et al. 2023). This prompted an investigation into the objectively measured physical fitness profiles of these medical students to identify the prevalence of fitness indices that are below average in this cohort. Poor general and cardiorespiratory fitness has been associated with a sedentary lifestyle and considered one of the biggest NCD risk factors. Despite the importance of producing healthy, physically active graduates as discussed above, few studies worldwide have reported on the physical fitness of medical students (Hao et al. 2014; Torres, Gordon, and Constantinou 2022; Stephens 2012).

Therefore, the primary aim of this study was to identify the prevalence of below average physical fitness in the four components of fitness (cardiorespiratory, flexibility, muscle strength, muscle endurance) in first-year medical students. A secondary aim was to describe differences in the average measures of the four fitness components in male and female participants.

This research could contribute to bridging the gap of knowledge that currently exists about physical fitness in future healthcare professionals, in this case in a tertiary institution in South Africa, where NCDs are a growing and persistent burden (Peer et al. 2014). Our findings could inform future interventions such as the development of health-promoting content and courses in the healthcare professionals' education system, in order to improve the behavioural risk factors identified as being out of the healthy range.

METHODS

Participants and procedures

The study design was a cross-sectional observational study conducted in 2019. Ethics approval was obtained from the Faculty of Health Sciences Research Ethics Committee at the University of Pretoria (REC no: 104/2019). Three-hundred and thirty-three registered first-year medical students at the University of Pretoria, South Africa were invited to participate. Two-hundred and fifty-six (77% of those invited to participate) gave their informed consent to participate in the research study.

A medical screening self-assessment of risk questionnaire (previously described (Schwabe et al. 2018; Schwellnus et al. 2019)) was administered via the online Smartabase platform (Fusion Sports Pty(Ltd), Australia). It is based on the European Association for Cardiovascular Prevention and Rehabilitation (EACPR) (Borjesson et al. 2011) recommendations and aims to identify those possibly at increased risk of acute medical complications during moderate-to-high intensity exercise. It includes questions related to history of cardiovascular disease (CVD), symptoms of CVD, risk factors for CVD and other chronic diseases. Participants were risk-stratified into one of four risk categories: very high, high, intermediate, and low, using an automated algorithm (Schwabe et al. 2018; Schwellnus et al. 2019). Those deemed not at risk in terms of readiness and safety to exercise based on the medical screening questionnaire (152 participants, 46 male and 106 female) performed physiological tests to assess four components of physical fitness: cardiorespiratory fitness, flexibility, muscle strength and muscle endurance.

Anthropometric measurements were taken including body mass (kg) and height (cm), measured with the InBody770 multi-frequency bioelectrical impedance (BIA) device (InBody Co Ltd, Korea). Body mass index (BMI) was calculated by dividing body mass (kg) by height squared (m^2). Resting blood pressure (BP) was measured using IntensCare

Automated Blood Pressure Monitors (Pharmamark, RSA) after the participant had been seated for five minutes. The participant's arm was supported at the level of the heart, and the relevant cuff was placed around the upper arm. Participants were asked not to consume caffeine or to smoke for at least 30 minutes before the tests. Resting heart rate was measured using a chest strap heart rate monitor and watch (Polar FT1/Polar FT2, Polar Electro Oy, Kempele, Finland).

Physical fitness tests

Four components of physical fitness were assessed using standardised tests that were supervised by experienced and registered healthcare professionals. Tests were performed in the same sequence and before each test was administered the procedures were explained thoroughly, giving the participants the opportunity to ask questions.

Cardiorespiratory fitness test:

The Young Men's Christian Association (YMCA) three-minute step test (Morrow 1995) was used to determine cardiorespiratory fitness. The test was conducted using a bench height of 30.5cm and a step rate of 24 steps.min^{-1} which was standardised using a metronome. The test lasted for 3 minutes and, once completed, the participants were instructed to sit down immediately and heart rate was measured using a heart rate monitor (Polar FT1/Polar FT2, Polar Electro Oy, Kempele, Finland). Heart rate was taken before the test, five seconds after the cessation of the test, and 1-, 3- and 5-minutes following cessation of the test. The 1-minute recovery heart rate was used to establish the score for the test and cut-off criteria of >=102bpm for males and >=113bpm for females were used to ascertain the prevalence of students with below average cardiorespiratory fitness (Morrow 1995).

Flexibility test:

Flexibility was evaluated using the sit-and-reach test (American College of Sports Medicine 2018). To start the test, participants sat with their head and back against a wall and the back of their knees flat against the floor. The ruler on the sit-and-reach box was moved to zero at the point of the participant's fingertips when their arms were straightened out in front of them, their back and the head still against the wall. The final results were obtained from three attempts to lean forward and move the ruler as far as possible with both legs remaining extended. The furthest distance reached was recorded in centimetres. American College of Sports Medicine (ACSM) guidelines were used to define a poor score for this test, which was <28cm for females and <25cm for males (American College of Sports Medicine 2018).

Muscle strength test:

Muscle strength was assessed using maximal handgrip strength (American College of Sports Medicine 2018) with a Jamar hydraulic hand dynamometer (Jamar hand-grip strength calliper Warrenville, Illinois, USA). The grip bar of the hand grip dynamometer was adjusted to fit the second joint of the fingers under the handle. The handgrip dynamometer was held in line with the forearm at the level of the thigh, away from the body. The participant squeezed the handgrip dynamometer as hard as possible without holding their breath. The test was repeated twice with each hand and the final score (to the nearest kilogram) was the combined score of the two highest attempts for each hand. The reference values used to establish the prevalence of poor maximal handgrip strength for this group were 52kg and 84kg for the females and males, respectively (American College of Sports Medicine 2018).

Muscle endurance tests:

Muscle endurance was assessed using a push up test and a sit up test. For the sit-up test, the participant lay in a supine position on a mat with his/her feet on the floor and his/her legs bent at a 90° angle, and performed as many sit-ups as possible in a minute, according to standard procedures (Morrow 1995). The main outcome variable was the number of sit-ups and values of <=34 for males and <=28 for females were used to define a “below average” performance (Morrow 1995). The push up test was administered with men starting in the standard "up position” (hands on the floor pointing forward and under the shoulder, back straight, head up, using the toes as the pivotal point) and women in the “modified knee push-up" position (legs together, knees on the mat with ankles plantar-flexed, back straight, hands on the floor shoulder width apart, head up, using the knees as the pivotal point) (American College of Sports Medicine 2018). The main outcome variable was the maximum number of push-ups performed in a minute. A score of <=21 for males and <=14 for females was used to define a “below average” performance (American College of Sports Medicine 2018).

Statistical analysis

All analyses were performed using a STATA V16 statistical package. Data collected via online questionnaires were extracted from the online Smartabase platform/app (Fusion Sports Pty(Ltd), Australia) to Microsoft Excel for further analysis. All fitness test data were manually entered into an Excel spreadsheet for further analysis. Normality of the continuous variables were checked using the Tukey ladder of powers. This method allows one to change the shape of a skewed distribution so that it becomes normal or nearly-normal. To detect cross-sectional differences in fitness scores between males and females, a one-way ANOVA was used. The Chi square test was used to assess sex differences in prevalence for fitness related categorical variables. Analysing these differences provides more comprehensive insights into the physiological characteristics of males and females. It facilitates the design of tailored interventions addressing specific needs, or educational interventions focusing on areas where gender-specific variations are observed, thereby contributing to evidence-based decision-making. The significance level was set at p-values lower than 0.05.

RESULTS

Descriptive characteristics of the participants

One-hundred and fifty-two first year medical students (46 males, 106 females, mean age 20.16±2.69 years) deemed not at risk to engage in exercise testing performed physiological tests to assess the four components of physical fitness. Table 1 presents demographic and physiological characteristics of this cohort of students.

Table 1. Demographic and physiological characteristics (mean ±SD) of first year medical students.

Physiological measurements taken	All participants	Male (N=46)	Female (N=106)	Male vs. female
	Mean±SD			p-value
Age (years)	20.16±2.69	20.35±3.41	20.08±2.33	0.57
Weight (kg)	65.34±13.16	75.43±10.89	60.96±11.59	<0.001*
Height (cm)	166.80±9.72	177.11±7.08	162.33±6.90	<0.001*
Body mass index (kg/m^2)	23.37±3.63	24.08±3.49	23.06±3.67	0.11
Resting heart rate (bpm)	77.51±12.32	73.02±10.63	79.45±12.54	0.003*
Systolic blood pressure (mmHg)	121.24±13.69	130.65±13.52	117.15±11.64	<0.001*
Diastolic blood pressure (mmHg)	70.86±11.28	70.52±13.27	71.01±10.36	0.81

**Significant difference (p<0.05) between males and females*

kg – kilograms; cm – centimetres; kg/m^2 – kilograms per meters-squared; bpm – beats per minute; mmHg – millimetres of mercury; SD – standard deviation

Prevalence of below average physical fitness measures in participants

The prevalences (%) of below-average measures of the four components of fitness in all participants and by sex are presented in Table 2. A high prevalence of low cardiorespiratory fitness was found in all participants (69.54%), with no statistically significant difference between males and females. Just under two-thirds (65.79%) of the group ranked below average for sit-ups (50.00% of males and 72.64% of females, significant difference p=0.007). Approximately 23% of participants fared poorly in the push-ups and 25.66% of the cohort (34.78% of males and 21.70% of females) had a handgrip strength that was rated below average. However, flexibility was excellent, with only 7.24% of the group scoring below average, with no significant difference between male and female participants.

Table 2. Prevalence of below average scores for the four components of fitness in all participants and by sex.

Fitness component tests performed	All		Male (N=46)		Female (N=106)		Male vs. female
	N	%	N	%	N	%	p-value
Heart rate recovery(bpm)[a]	105	69.54	36	78.26	69	65.71	0.12
Sit-and-reach test (cm)	11	7.24	5	10.87	6	5.66	0.26
Handgrip strength (kg)	39	25.66	16	34.78	23	21.70	0.09
Push-ups (count)	35	23.03	13	28.26	22	20.75	0.31
Sit-ups (count)	100	65.79	23	50.00	77	72.64	0.007*

**Significant difference (p<0.05) between males and females*

[a] One female participant did not reach the end of the step test so N-1

kg – kilograms; cm – centimetres; bpm – beats per minute

Assessment of the components of physical fitness

Physical fitness assessment scores for the four fitness components for the whole group and by sex are presented in Table 3. The average measure of cardiorespiratory fitness, assessed with

1-minute heart rate recovery following a sub-maximal step test, was not statistically significantly different between sexes (115.96±16.09bpm for males and 117.08±22.87bpm for females). The female participants in the group were statistically significantly more flexible than the male participants, with mean (±standard deviation (SD)) measurements of 40.61±8.40cm for females vs 36.70±9.31cm for males ($p=0.012$). However, with respect to muscle strength and muscle endurance the males performed statistically significantly better than the females. Here, the mean maximal handgrip strength in the male participants was 88.96±12.04kg while in the female group it was 59.34±10.36kg ($p<0.001$). The mean number of sit-ups performed by the male participants was 33.46±9.04 and the females performed 24.48±12.18 ($p<0.001$). Lastly, the mean push-up score for the male participants was 30.28±13.95 while the female participants scored 24.27±12.35 ($p=0.009$).

Table 3. Physical fitness parameters (mean ±SD) of a cohort of first year medical students.

Fitness component tests performed	All participants	Male (N=46)	Female (N=106)	Male vs. female
	Mean±SD			p-value
Heart rate recovery (bpm)[a]	116.74±20.99	115.96±16.09	117.08±22.87	0.76
Sit-and-reach test (cm)	39.43±8.84	36.70±9.31	40.61±8.40	0.012*
Handgrip strength (kg)	68.31±17.44	88.96±12.04	59.34±10.36	<0.001*
Push-ups (count)	26.09±13.11	30.28±13.95	24.27±12.35	0.009*
Sit-ups (count)	27.20±12.03	33.46±9.04	24.48±12.18	<0.001*

**Significant difference (p<0.05) between males and females*

[a] *One female participant did not reach the end of the step test so N-1*

kg – kilograms; cm – centimetres; bpm – beats per minute; SD – standard deviation

DISCUSSION

This study revealed poor cardiorespiratory fitness and poor muscle endurance (sit-ups) in a first year medical student cohort at a South African tertiary institution, with about two-thirds having low cardiorespiratory fitness, and low muscle endurance in a sit-up test. One-third of male participants and one-fifth of female participants in this group had below average handgrip strength. The objectively measured poor physical fitness results in the current study correlate with the high prevalence of low habitual physical activity that was self-reported by participants in a previous study by this research group. International guidelines regarding physical activity for adults recommend regular strength and flexibility exercise, in addition to cardiorespiratory activity (American College of Sports Medicine 2018; Pate et al. 1995). The proportion of male and female students with below average fitness scores did not differ significantly between sexes with respect to any of the components of fitness. However, if one looks at the absolute measurements, the male participants in our cohort performed better than the female participants in muscle strength and endurance tests, whereas the female participants performed better in the flexibility test. This is in agreement with other research that has tested the components of fitness in University students (Liposek 2018; Pituk 2019; Jourkesh 2011; Ding and Jiang 2020).

Cardiorespiratory fitness and maximal handgrip strength have been identified as the most important and well-studied markers for physical fitness and NCD risk assessment (Ortega et al. 2018). Furthermore, it has been shown that young adults with reduced cardiorespiratory fitness and handgrip strength are significantly more likely to develop cardio-metabolic diseases compared to their fitter counterparts (Diez-Fernandez et al. 2018). Hoyos et al., who evaluated aerobic fitness in university students using relative VO_2max, found that poor physical fitness was associated with higher cardiovascular disease risk, which was of concern particularly in their male sub-group, where aerobic capacity was poor (Hoyos et al. 2011). There are multiple benefits to good cardiorespiratory fitness and optimal muscle strength including an increased insulin sensitivity, decreased body fat, enhanced β-cell function, and an increased basal metabolic rate (Williams et al. 2007; Grontved et al. 2013). Also, it seems that all favourable effects of cardiorespiratory fitness are reinforced by a higher muscle mass or muscle strength (Williams et al. 2007; Braith and Stewart 2006). These positive effects are not surprising as 85% of the body's glucose is stored in muscle mass which plays a crucial role in systemic glucose metabolism. Repeated muscle contraction stimulates the uptake of glucose from the blood and stimulates insulin sensitivity (Andersen et al. 2003). It is therefore of concern that 69.54% of the medical students in our study show below average cardiorespiratory fitness and 25.66% scored below average with regard to maximal handgrip strength.

These findings are concerning for a number of reasons. Firstly, it has been shown that the period of transition to adulthood is an important life stage with regard to making decisions about one's own health management, including habits related to physical activity and fitness (Harris 2010). Moreover, it seems that the beginning of university studies is a crucial period in which physical activity habits and choices for later life are formed through decisions made by the young adult, especially with regard to leisure time. It has been documented that many young students give up leisure time physical activity or sports at the time they enter university because these activities are no longer part of their curriculum (Dovey, Reeder, and Chalmers 1998). The most common reasons given by students for giving up physical activity is lack of time and other priorities (Romaguera et al. 2011). Unfortunately, although physical fitness has an important positive influence on academic achievement (Castelli et al. 2007; Grisson 2005; Van Dusen et al. 2011), a notable decline has been observed as the young adult enters a tertiary institution (Kwan et al. 2012; Bray and Born 2004).

Secondly, it is concerning to find these results in a group of future healthcare professionals where the inclusion of health behaviours into their referral and counselling practices depend on their own individual lifestyles. This implies that the lifestyle health behaviours of practitioners themselves could have an important impact on future community health behaviours (Walsh et al. 1999; Lewis et al. 1991; Epel and Ziva Regev 2000; Glasgow et al. 2001; van der Ploeg et al. 2007). Healthcare professionals are in a key position to promote habitual physical activity because they are viewed as a credible source of health information and will regularly consult with patients at risk. Evidence reveals that physically active doctors are more likely to prescribe physical activity in their practice, however exercise prescription remains low in many cases (Walsh et al. 1999; Lewis et al. 1991; Epel and Ziva Regev 2000; Glasgow et al. 2001; van der Ploeg et al. 2007; Kasina, Ramella, and Paladugu 2015). Moreover, it has been shown that patients trust more and comply more with health advice given by doctors whom they perceive to be healthy (Puhl et al. 2013). Therefore, to help create a healthier population, tertiary educational institutions have an opportunity to promote physical fitness as part of a healthy lifestyle to future healthcare professionals.

We recommend that a tertiary institution implement programmes to improve the physical fitness and knowledge of students. Strategies to encourage participation in exercise include making time available or providing facilities at a reduced cost, in order to mitigate perceived barriers and increase access, along with health promotion initiatives to create awareness. Information about the importance of physical activity for health and ways to incorporate activity into one's life should be included in the medical curriculum, as part of broader education around NCD risk factors and their prevention. Tertiary institutions should aim to have a positive effect on lifestyle related risk factors from NCD education and progress could be made throughout the study program with the implementation of physical activity programs in order to reduce the prevalence of NCD risk factors. The focus of the current five-year strategic plan of South Africa is prevention – focussing on modifiable risk factors – which aligns with the findings of this study (Health 2022). A dedicated preventive medicine programme for University students would be in line with this.

The first limitation of this study is that cardiorespiratory fitness was indirectly calculated, based upon their heart rate recovery values after a submaximal step test and not by direct measurement of oxygen consumption. A second limitation was that a number of participants who consented to participate in this study were excluded from participating in the physical fitness tests based on the outcome of a pre-exercise medical screening questionnaire, which is based on EACPR recommendations. Participants were risk-stratified into one of four risk categories: very high, high, intermediate, and low, using an automated algorithm. Only those deemed not at risk in terms of readiness and safety to exercise based on the medical screening questionnaire performed the fitness tests. It is therefore possible that participants that were excluded could be less fit than those who participated. As such, the prevalence of low cardiorespiratory fitness of this group could be under-reported and actually be higher. Finally, we acknowledge that this was a cross-sectional study and the assessment of the fitness parameters were measured at one point in time. We recommend that future research should investigate longitudinal changes in health behaviours over time, using objective measures such as pedometers or other activity monitors.

In summary, this study shows that a group of first year medical students generally have poor measures of fitness. With physical activity and fitness being the most important NCD-related risk factor, these are important findings and should be investigated further, considering the importance of how future healthcare professionals will consult their patients to promote health and reduce the NCD burden. Studies such as these may also assist tertiary institutions to identify the required interventions, and the development of programs to improve the health, wellbeing and academic performance of students.

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DECLARATION OF CONFLICTING INTERESTS:

The authors declare that there is no conflict of interest

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