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Activity Participation and Neuromuscular Fitness of Medical Students: A Cross-Sectional Study

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Abstract: *This study aimed to compare activity participation patterns, leg neuromuscular performance, and lean body mass between medical and non–medical students. Forty-seven medical students and 64 non–medical students' habitual physical activity level was assessed using the International Physical Activity Questionnaire short form. The peak torque and the time to peak torque for the knee extensor and flexor muscles were measured using isokinetic dynamometry. The leg muscle reflex contraction time was estimated using surface electromyography and accelerometry. Lean body mass was quantified from a whole-body dual-energy X-ray absorptiometry scan. Medical students spent 2.73 hours less time in exercise per week than the non–medical students ($p < 0.001$). In addition, the medical students had 20.48% higher isokinetic peak torque of knee flexors ($p = 0.034$), and their time to peak torque of knee extensors was 66.06 ms shorter ($p = 0.007$) than that of the non–medical students. Medical students demonstrated better knee muscular performance than non–medical students even though they exercised less. Further studies are required to explore factors that contribute to the medical students' superior knee muscular performance and the adverse effects associated with inadequate exercise.*

Keywords: *Activity Participation; Lifestyle; Physical Fitness; Muscle Mass; Medical School Curriculum; Undergraduate Students*

1. INTRODUCTION

Medical education is well known to be demanding and stressful. The long hours of study needed to pursue a medical degree might leave medical students less time for physical activity or exercise (Likus, Milka, Bajor, Jachacz-Lopata, & Dorzak, 2013; Majeed, 2015) and thus result in suboptimal physical fitness (Stephens, Cochran, Hall, & Olsen, 2012). However, regular physical activity or exercise and a supreme physical fitness level are essential for medical professionals because those who are physically fit have a greater likelihood of counseling their patients about exercise, health, and disease prevention (Lobelo, Duperly, & Frank, 2009). No study has investigated the physical and sedentary activity participation patterns of medical students in Hong Kong. In addition, the habits of medical students regarding exercise (i.e., a subset of physical activity that is planned, structured, and repetitive and has an objective of improving physical fitness) (Caspersen, Powell, & Christenson, 1985) are not known.

Physical fitness is the consequence of regular exercise, and only one research team in the United States has studied it in medical students (Stephens et al., 2012). In a study of all medical student participants enrolled at the Uniformed Services University and on active duty in the US Army, Navy, or Air Force, physical fitness levels were shown to decline during medical school, and the decline was most notable during the preclinical years (Stephens et al., 2012). Based on the findings of this study, we hypothesized that medical students may have a physical fitness level inferior to that of general university students.

It is widely acknowledged that physical fitness has five health-related components: (a) muscular strength, (b) muscular endurance, (c) body composition (lean mass and fat mass), (d) flexibility, and (e) cardiorespiratory endurance (Caspersen et al., 1985). Muscular fitness may be the most important of these basic components because it significantly affects physical health and well-being in both healthy and unhealthy adults (Metter, Talbot, Schrager, & Conwit, 2002; Janssen, Heymsfield, & Ross, 2002). In particular, skeletal muscle strength is a predictor of all-cause mortality risk (Metter et al., 2002), and skeletal muscle mass (lean mass) is associated with functional performance (Janssen et al., 2002). We therefore focused on studying medical students' muscular fitness in this study. We sought to compare the physical and sedentary activity participation patterns, leg neuromuscular performance, and lean mass between medical and non–medical students. It was hypothesized that medical students might participate less in physical activities and exercises, spend more time in sedentary activities, and have a lower muscular fitness level (inferior neuromuscular performance) and lean body mass. Our results might encourage medical schools to incorporate physical activity/exercise programs as a routine part of their curriculum to improve their students' physical (neuromuscular) fitness.

2. METHODS

In this cross-sectional and exploratory study, 47 students in a Bachelor of Medicine and Bachelor of Surgery (MBBS) program (i.e., the medical student group) and 64 students in non–medical areas (i.e., the non–medical student group) were recruited from the University of Hong Kong (HKU) community by convenience sampling between August and September 2017. To meet the inclusion criteria, participants were required to be between 18 and 25 years of age and an undergraduate student at HKU. The exclusion criteria were enrollment in the Faculty of Dentistry or Faculty of Law (for the non–medical student group) or a postgraduate program; body-building activity (i.e., regular resistance training and dietary supplements); a family history of genetic disorder; pregnancy; recent injury that may affect the test results; muscle fatigue on the day of measurement; a significant musculoskeletal, neurologic, cardiorespiratory, renal, endocrine, or metabolic disorder; or a metallic implant.

Ethical approval was provided by the HKU/Hospital Authority Hong Kong West Cluster Institutional Review Board. Each participant gave written informed consent before the tests began. Data collection was performed in HKU's Physical Activity Laboratory and Dual-Energy X-ray Absorptiometry (DXA) Laboratory by 11 MBBS students supervised by two experienced physiotherapists. All procedures were conducted in accordance with the Declaration of Helsinki and the STROBE reporting guidelines were followed.

Short interviews were carried out to obtain the participants' basic demographic information, including age, sex, and exercise and sedentary activity (e.g., studying) participation patterns. The International Physical Activity Questionnaire short form was used to evaluate the participants' habitual physical activity level. Habitual physical activities include (a) vigorous physical activities, such as heavy lifting, digging, or fast bicycling in daily life; (b) moderate physical activities, such as carrying light loads or cycling at a regular pace in daily life; and (c) walking at work and at home or walking to travel from place to place. Body weight and height were also measured before the physical outcomes were assessed. Each participant underwent the following physical tests in a random order.

The isokinetic concentric muscular performance of the knee extensors and knee flexors in each participant's right leg was tested using a Biodex System 4 Pro isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY), a valid and reliable tool for measurement of muscle strength and performance in healthy young adults (Drouin, Valovich-McLeod, Shultz, Gansneder, & Perrin, 2004), following the standardized assessment procedures recommended by the manufacturer (Biodex Medical Systems Inc., 2014). In brief, each participant sat on the chair of the isokinetic machine with the hips at 85° flexion. The knee joint axis, demarcated by the lateral epicondyle of the femur, of the right leg was aligned with the rotational axis of the isokinetic dynamometer. The participants' other body parts were stabilized with straps to ensure that an isolated knee flexion/extension movement was performed. The testing range of motion was the participant's full knee flexion–extension range, and a test velocity of 120°/s was chosen. To eliminate the effect of gravity on knee muscle torque, gravity effect torque correction was performed at 30° of knee flexion (Biodex Medical Systems Inc., 2014). A familiarization trial with five submaximal knee flexion/extension repetitions was performed before the test ensemble of five maximal concentric contractions of the knee extensors and flexors was performed. All participants were provided with consistent verbal encouragement to ensure maximal contraction of the knee muscles at the preselected velocity. The average body weight–adjusted isokinetic peak torque (%) and time to peak torque (in ms) of the knee flexor and extensor muscles were derived and used for analysis (Biodex Medical Systems Inc., 2014).

Surface electromyography (EMG; Biometrics, Newport, UK) was used to measure the leg neuromuscular responses following unexpected posterior-to-anterior (PA) and anterior-to-posterior (AP) trunk perturbations. An accelerometer (ACL300, Biometrics) was attached to the participant's sternum to register the onset of trunk perturbation (Fong & Ng, 2006). Physiologically, a sudden PA perturbation to the trunk would trigger reflexive contractions of the hamstrings and gastrocnemius, and a sudden AP perturbation to the trunk would trigger reflexive contractions of the quadriceps and tibialis anterior, thus allowing the participant to maintain postural stability (Fong et al., 2015). Circular Ag/AgCl bipolar surface EMG electrodes (EMG sensor SX230-1000, Biometrics) were used to record the reflex activities of these four major postural muscles in the right leg in response to PA or AP trunk perturbation (Fong & Ng, 2006). The active electrode placement sites were identified following the recommendations of Barbero et al. (Barbero, Merletti, & Rainoldi, 2012). The skin was prepared by shaving, light abrasion with fine sandpaper, and cleansing with alcohol swabs to reduce skin impedance, as necessary. The EMG active electrodes were fixed over the center of each muscle belly and placed in a line parallel with the longitudinal axis of the leg. A reference electrode (R506, Biometrics) was placed on the ipsilateral lateral malleolus. Regarding the technical details of the EMG electrodes, the center-to-center interelectrode distance was 2 cm. All EMG signals were filtered with a bandwidth of 20 to 460 Hz, sampled at 1000 Hz, and amplified by a gain factor of 1000 using a single differential amplifier with an input impedance of greater than 1015 Ω and a common mode rejection ratio of greater than 96 dB (Biometrics Ltd., 2012). In addition, all EMG electrodes and accelerometers were connected to a DataLOG (Biometrics) that was securely attached to the participant's waist during the test to minimize artifacts. The DataLOG uses both a high-pass filter (20 Hz) and a low-pass filter (450 Hz) and stores EMG and accelerometer signals for offline analysis (Biometrics Ltd., 2012).

A trunk perturbation test was used to stimulate leg muscle activity. The test procedure was modified from our previous studies (Fong & Ng, 2006; Fong et al., 2015). In brief, each participant closed his or her eyes and stood with bare feet at shoulder width and arms resting by the side of the body. The participant was instructed not to take any corrective steps during the test. The assessor then gave a sudden horizontal push to the participant's back (PA perturbation) or chest (AP perturbation) at around the level of T12 to disturb his or her balance. Leg muscle EMG activity was measured for 3 s before the perturbation and 3 s after the onset of the perturbation. Only one testing trial was performed to avoid anticipation and learning (Fong et al., 2015).

The EMG signals from each leg muscle and the accelerometer signal were post processed using the Biometrics EMG analysis software for Data LOG version 8.51. The onset of EMG muscle activation (defined as the starting point of EMG activity of each muscle that lasts for more than 25 ms and is two standard deviations away from the mean resting EMG value) (Fong & Ng, 2006) and the onset of the accelerometer signal (defined as the time point at which the signal amplitude is 0.20 ms-2 away from the resting value) (Fong et al., 2015) were identified. Finally, the muscle activation onset latency, defined as the time interval (in ms) between the onset of the accelerometer signal and the first discernible EMG activity of each leg muscle, was calculated and used for analysis (Fong & Ng, 2006).

Each participant also underwent a whole-body scan with a Horizon A DXA scanner (Hologic Inc., Bedford, MA) performed by a licensed operator following standardized procedures as described in the Hologic user manual (Hologic Inc., 2015). After the scan, the participants' total body and lower limb lean mass were determined using the DXA scanner's region of interest program, and these variables were used in the outcome analyses. In addition, the lean mass divided by the square of the height was reported as a demographic parameter because it represents the participants' weight status more accurately than the body mass index.

SPSS software version 24.0 (IBM, Armonk, NY) was used to perform the statistical analyses. A two-tailed significance level of 0.05 was set. Descriptive statistics were calculated for both demographic and outcome variables. Kolmogorov-Smirnov tests and/or histograms were used to check the normality of the data. Independent *t*-tests and chi-square tests were used to compare the continuous and categorical demographic characteristics, respectively, between the groups. To account for the possible confounding effect of demographic data when comparing the outcome variables between the two groups and to avoid the possibility of a type I error, multivariate analysis of covariance was performed three times. The first analysis incorporated all isokinetic outcomes, the second incorporated all outcomes related to leg muscle activation onset latency, and the third incorporated all activity participation outcomes. Two separate one-way analyses of covariance were then performed to compare the groups' DXA-derived right leg lean mass and total body lean mass. The effect size (partial eta-squared) was also reported. By convention, values of 0.14, 0.06, and 0.01 represent large, medium, and small effect sizes, respectively.

3. RESULTS

Forty-seven medical student and 64 non–medical student volunteers were screened by 2 physiotherapists and 5 student assistants in September 2017. All were eligible for the study. The participant characteristics were similar between the two groups except that the medical students were 0.9 years younger than the non–medical students (p = 0.001; Table 1). Therefore, age was treated as a covariate in the subsequent statistical analyses.

Table 1 Participant characteristics.

	Medical students (n = 47)	**Non–medical students (n = 64)**	**p**
Age, y	19.13 ± 1.23	20.06 ± 1.70	0.001*
Sex (male/female), n	25/22	36/28	0.749
Body weight, kg	58.39 ± 10.98	61.09 ± 12.17	0.232
Height, m	1.68 ± 0.09	1.67 ± 0.09	0.485
DXA lean mass/height^2, kg/m^2	14.03 ± 1.79	14.72 ± 2.18	0.086

The results of multivariate analysis of covariance revealed an overall difference in isokinetic outcomes between the two groups that approached significance (Hotelling's trace = 0.093; F(4,102) = 2.364; p = 0.058). When each individual isokinetic outcome was considered, the between-groups difference was significant for the body-weight–adjusted isokinetic peak torque of the knee flexors (p = 0.034) and the time to the isokinetic peak torque of the knee extensors (p = 0.007). Specifically, the medical students had a 20.48% higher isokinetic peak torque of knee flexors and a 66.06 ms shorter time to peak torque of the knee extensors. The partial eta-squared values ranged from 0.042 to 0.078, indicating medium effect sizes (Table 2).

Table2. *Comparison of outcome measurements between the two groups*

	Medical students (n = 47)	Non–medical students (n = 64)	Mean difference between groups (95% confidence interval)	p	Effect size
DXA lean mass, g					
Right leg	7108.34 ± 1661.50	7801.93 ± 5544.96	-693.59 (-2717.55, 719.97)	0.252	0.013
Total body	47979.87 ± 49520.07	41139.58 ± 8897.35	6840.29 (-1905.54, 24830.08)	0.092	0.028
Body-weight-adjusted isokinetic peak torque of right knee muscles at 120°/s, %					
Knee extensors	164.77 ± 45.37	147.24 ± 56.04	17.53 (-4.00, 37.89)	0.112	0.024
Knee flexors	98.28 ± 67.82	77.80 ± 29.27	20.48 (1.69, 41.67)	0.034*	0.042
Time to isokinetic peak torque of right knee muscles at 120°/s, ms					
Knee extensors	411.52 ± 104.48	477.58 ± 143.83	-66.06 (-124.10, -20.40)	0.007*	0.068
Knee flexors	427.78 ± 134.90	490.97 ± 211.87	-63.19 (-137.17, 11.04)	0.094	0.026
Right leg muscle activation onset latency, ms					
Quadriceps	93.09 ± 33.49	81.02 ± 27.37	12.07 (-5.02, 24.06)	0.196	0.022
Tibialis anterior	98.22 ± 43.39	94.22 ± 40.51	4.00 (-14.60, 26.04)	0.576	0.004
Hamstrings	82.47 ± 23.88	83.91 ± 25.56	-1.44 (-11.65, 12.47)	0.946	<0.001
Gastrocnemius	73.69 ± 23.96	82.51 ± 25.94	-8.82 (-22.21, 2.28)	0.109	0.034
Activity participation patterns					
Time spent in exercises , hours per week	2.34 ± 2.09	5.07 ± 4.43	-2.73 (-4.20, -1.30)	<0.001*	0.130
IPAQ (habitual physic al activity) total score, MET-min per week	1525.12 ± 1541.28	1894.75 ± 1970.92	-369.63 (-1101.13, 361.88)	0.318	0.010
Time spent in sedent ary activities, hours per week	22.41 ± 17.93	17.66 ± 15.41	4.75 (-1.98, 11.48)	0.164	0.020

Note. DXA = Dual-energy X-ray absorptiometry, IPAQ = International Physical Activity Questionnaire (short form), MET = metabolic equivalent of task.

Means ± standard deviations are presented.

*$p < 0.05$

Moreover, multivariate analysis showed that activity participation patterns differed between the groups (Hotelling's trace = 0.108; $F(3,92) = 3.320$; $p = 0.023$). Further analysis revealed that the medical students spent 2.73 hours less time in exercise every week than the non–medical students ($p < 0.001$; partial eta-squared, 0.130 [large effect size]). No significant between-groups differences were noted in any other outcome variables ($p > 0.05$), and the effect sizes were small (Table 2).

4. Discussion

To the best of our knowledge, this study was the first to investigate the activity participation patterns of medical students in Hong Kong. We found that the medical students spent only 2.34 hours per week on exercise, which was less than half of that of the non–medical students (5.07 hours per week), although the habitual physical activity levels (i.e., walking and vigorous and moderate physical activities in daily life) and time spent in sedentary activities were similar between the two groups. Our findings concur with those of a previous study in which the habitual physical activity levels of students of medical and non–medical universities were shown to be similar (Baradaran-Rezaei, Shirvani, & Fathi-Azar, 2008). However, medical students rarely or never participated in exercises because they did not have the time (Likus et al., 2013; Majeed, 2015) or energy (Likus et al., 2013). It has been reported that exercise (structured physical activity) decreased during the freshman year (Wolf & Kissling, 1984), and this unhealthy behavior may progress as students advance through medical school (Stephens et al., 2012; Rustagi, Taneja, Mishra, & Ingle, 2011). Our medical student group, comprising year 1 to year 6 medical students, therefore demonstrated a significantly shorter period of exercise per week overall than the non–medical students.

Although the medical students spent less time in exercises every week, they demonstrated greater maximum isokinetic muscle strength of the knee flexors and a shorter time to reach peak muscle strength in the knee extensors than the non–medical students. The maximum muscle strength of the knee extensors and the time to peak torque of the knee flexors were similar between the two groups. The medical students' overall better knee neuromuscular performance may be explained by genetic influences (Arden & Spector, 1997) and by better motor unit synchronization and coordination (Enoka, 1988). Of course, further studies are required to confirm our postulations and explore other factors that contributed to the medical students' superior neuromuscular performance even though they exercised less.

Regarding the leg neuromuscular responses following a trunk perturbation test, our findings reveal similar leg muscle activation onset latencies between the medical and non–medical students. The finding was not entirely surprising because muscle synergies (muscle EMG onset latency) are influenced by pathology (Beckman & Buchanan, 1995; Karst & Willett, 1995), neuromuscular exercise training (Clark & Burden, 2005), and central motor programs (Torres-Oviedo & Ting, 2007). None of our participants had neurologic or musculoskeletal disorders or received specific neuromuscular exercise or balance training. In addition, both groups of participants spent similar time in habitual physical activities. Therefore, our healthy medical and non–medical students had similar leg muscle activation onset latencies.

No significant between-group differences were found for the lean mass measures. The findings were anticipated because lean mass gain in young adults relies primarily on dietary protein intake and high-volume resistance training (Longland, Oikawa, Mitchell, Devries, & Phillips, 2016). None of our participants took dietary supplements or excessive protein or undertook regular high-volume resistance training; therefore, their total body lean mass was normal or close to the norm (Longland et al. 2016; Nguyen, Howard, Kelly, & Eisman, 1998). Moreover, because the lean mass of the right leg was not greater in the medical student group, the medical students' higher knee flexor muscle strength is not explained by leg lean mass.

This study has some inherent limitations. First, we did not differentiate freshman-year, preclinical-year, and senior-year medical students, but they may have participated in different levels of physical activity (Frank, Tong, Lobelo, Carrera, & Duperly, 2008; Stanford, Durkin, Blair, Powell, Poston, &

Stallworth, 2012) and demonstrated different levels of physical fitness (Stephens et al., 2012). Second, our activity participation outcomes were all self-reported and are thus susceptible to social desirability bias and recall bias; the participants may have overreported their physical activity participation time (Sallis & Saelens, 2000). Third, this was a cross-sectional study, so no causal relationship can be established between medical training and activity participation and neuromuscular performance. Finally, our results may not be generalizable to medical and non–medical students in other countries. Indeed, medical students in different countries may demonstrate different activity participation patterns (Likus et al., 2013; Majeed, 2015; Baradaran-Rezaei et al., 2008; Rustagi et al., 2011; Frank et al., 2008). Larger prospective studies including medical and non–medical students in different countries are warranted.

Our findings have some implications for the promotion of exercise in the medical school curriculum. Although the adverse neuromuscular effects associated with inadequate exercise were not found in this study, it is well documented that persistent inadequate exercise can lead to obesity, lower metabolic function, endocrine changes, lower cardiorespiratory fitness, psychosocial problems, and even death (Sandler & Vernikos, 1986; Williams, 2013). Therefore, medical schools should consider the incorporation of exercise programs into their curriculum to increase their students' exercise participation and prevent possible complications associated with inadequate exercise.

5. Conclusion

Medical students showed better knee muscular performance than non–medical students even though they spent less time in exercise. Habitual physical activity and sedentary activity participation, lean mass, and leg muscle reflex contraction time were similar between the two student groups. Further studies are required to explore factors that contributed to the medical students' superior knee muscular performance. Moreover, our results may encourage medical schools to incorporate exercise programs as a routine part of their curriculum to increase their students' exercise participation.

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