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Original Investigation

Association of physical activity and physical fitness with gait speed in female university students

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Purpose: Associations of gait speed with physical activity and physical fitness are well studied in population of older adults, but such studies are lacking in the population of young adults. This cross-sectional study aimed to explore the association between 1) physical activity and gait speed 2) physical fitness components and gait speed.
Methods: A total of 198 first- and second-year female students (age 19.28 ± .98 years; stature 166 ± 6.3 cm; body weight 62.37 ± 11.8 kg; body-mass index (BMI) 22.68 ± 4.22 kg/m2) attending university were recruited. To assess gait speed, we used a 4-meter gait speed test. To assess muscle fitness, we used to stand broad jump was used and to assess motor fitness we used 4×10-meter shuttle run test. We used International Physical Activity Questionnaire-Short Form (IPAQ-SF) to assess the level of physical activity.
Results: Univariate regression analysis showed that only 4×10 m shuttle run test was associated with gait speed (β= - .021). In unadjusted multivariate regression analysis model only 4×10 m shuttle run test (β= - .034) was associated with gait speed. In a model adjusted for body-mass index and age only 4×10-meter shuttle run test (β= - .033) was associated with gait speed.
Conclusions: Our study shows a significant association between motor fitness and gait speed in female university students. Those with low levels of motor fitness should be included in exercise programs to enhance their fitness and prevent any potential gait abnormalities.

Keywords: gait assessment, motor fitness, muscle fitness, physical health, young adults.

Introduction

Walking is a natural activity of everyday life and a usual form of physical activity (PA). Humans can walk at various speeds, but for everyday activities the usual gait speed is around 4-5 km/h[1]. Usual gait speed or often referred to as preferred walking speed is the most comfortable speed at which humans freely choose to walk. It is considered as an important marker of health and mobility[2,3] and can be influenced by factors such as age, gender, height, weight and PA[4]. Body characteristics such as wider pelvis and less muscles mass in women comparing to men can also have an impact on gait characteristics resulting in higher cadence, shorter stride length and narrower stride length[5]. Furthermore, gait analysis can be a useful tool in the development and management of rehabilitation programs and assessment of sports performance[6,7].

Regular participation in physical activity (PA) is necessary to maintain health. Studies show that regular PA lowers the incidence of cardiovascular, metabolic and mental illness[8]. Different training modalities can also induce various cognitive changes. Participation in regular aerobic exercise has a positive impact on mental well-being, executive functions, spatial memory, processing speed and can also reduce depression scores. Resistance training shows similar effects with improvements in problem solving, attention, working memory, executive functions and cognitive flexibility. Concurrent training, which is an integration of aerobic and resistance training, shows heterogeneous results across studies. The studies showing positive effects mostly demonstrate enhancements in memory, executive function, attention and dual task performance[9].

One of the biggest problems in today's world is physical inactivity. According to a recent systematic review, university students engage in a satisfactory level of PA, although the results vary between countries mostly due to cultural differences, educational systems and guidelines between the organizations[10]. Results from Croatian students[11] show that a little bit less than 30 percent of both male and female students don't meet the standard PA levels according to WHO standards[12]. Furthermore, newer studies on biomedical students also show satisfactory levels of PA in Croatian students[13].

Along with PA, physical fitness is recognized as one of the most important health markers. Physical fitness is a construct that consists of four dimensions which are body composition, cardiorespiratory, musculoskeletal and motor fitness. Those dimensions can include multiple components such as speed, agility, flexibility, etc. Physical fitness has an important role in performing physical exercise and PA[14,15]. All dimensions of physical fitness can be objectively measured in the laboratory or field-based settings[16].

Most of the research on gait speed was conducted on a sample of older adults considering their gait speed can be used as a marker of health and a predictor of falls in older adults[17]. Previous studies on older adults show a significant association between PA and gait speed[18]. Furthermore, there have been numerous studies exploring the associations between physical fitness and gait speed in older adults[19-22]. Gait assessment is important not only for older adults but also for young adults to identify gait abnormalities and intervene to delay any potential impairment. Gait normative values can be of great significance for clinicians in assessing gait and evaluating the magnitude of intervention programs.

Studies aiming to explore the association of physical activity and physical fitness with usual gait speed in young adults are lacking. Therefore, the main purpose of this study was to explore the association between physical activity and physical fitness with usual gait speed in young adults.

Methods

Participants

In this cross-sectional study, participants were first- and second-year university students. Participants were introduced to the measurement protocol, potential contribution of the research and possible discomforts during the execution of the research. Exclusion criteria were any previous injuries of the lower extremities in the last six months. The initial sample consisted of 215 participants. Of these, four participants could not perform all the fitness tests due to a recent lower extremity injury or were excluded because of a lower extremity injury that occurred in the last six months and thirteen did not provide full data. The participants that did not have all the data were removed from the final analysis. Therefore, the final sample consisted of 198 students (100% female). All participants had given their oral consent before entering the study and were informed that the study was voluntary, and they could withdraw at any time. The research protocol was approved by the Ethics committee prior to the start of the investigation. The procedures performed in this study were anonymous and in accordance with the Declaration of Helsinki.

Study design and methodology

All measurements were taken in one session inside the sports facilities of the faculty the participants are attending. The total duration of the study was 2 weeks in total. Firstly, anthropometric measures of the participants were taken, and gait speed was measured afterwards. Before performing physical fitness tests a short warm-up was conducted to ensure the best results.

Body height was measured in stocking feet with participants standing upright against a stadiometer (Seca, Japan) with the precision of .10 cm. Body weight was measured with electronic scale (OMRON, Model BF511 Blue, Japan) with the precision of .10 kg, and the participant wore light clothes with no shoes. Body mass index (BMI) (kg/m^2) was calculated as weight (in kilograms) divided by the square of height (in meters).

Muscular fitness was assessed using the standing broad jump test. Each participant performed distance jumps from a standing start. The participant's starting position was behind a starting line in a standing stance with feet approximately shoulder's width apart. While performing the jumps, the subjects were asked to bend their knees at approximately 135 degrees with their arms in front of them, parallel to the ground, then to swing both arms backwards, push off vigorously while swinging the arms forward and jump forward as far as possible, trying to land with their feet together and stay upright. Trials were repeated if the participants took an extra step after landing or could not stay on the spot after landing. The jump distance between the heel of the participants' foot closer to the starting point was measured with a measuring tape taped to the floor[23]. The best out of three attempts was taken as the final score expressed in centimeters.

Motor fitness was assessed with the 4×10-meter shuttle run (4×10mSRT) test of speed-of-movement, agility, and coordination. Two lines 10 meters apart were drawn on the floor using tape, each 1 meter long and both parallel to one another with two cones put on both lines. This test involves running and turning at maximum speed between two parallel lines (10 m apart), covering a total distance of 40 m and crossing each line with both feet every time. Participants had to run from the starting line to the other line as fast as possible, pick up a cloth located approximately .5 meters behind the line, return to the starting line as fast as possible, drop the cloth on the floor and switch it for another one, run back to the other line, repeat the process of dropping and picking up a new cloth before running back to the final line. After the participant crossed the final line with one foot the measurement was stopped[24,25]. The test was performed three times, and the fastest time was recorded in seconds. This test is associated with bone mass in young people and is also a marker of speed and agility[15].

To measure gait speed, participants were assessed on a 4-meter gait speed test. Participants performed the test three times over four meters and the time was recorded using a stopwatch (within .01 seconds). The walkway was 12 meters long. Gait speed was measured between the fourth and eight meter so the participants could establish their normal gait pattern in the first four meters. Participants were instructed to walk to the other end of the course at their usual speed, just as if they were walking down the street. Timing with a stopwatch began when the first foot passed the starting line (4-meter mark) and ended when the first foot passed the finish line (8-meter mark). The fastest time of the three attempts was used for analyses. To calculate the gait speed, distance (4-meter) was divided by time the participant took to complete the course[26].

As a measure for assessing different levels of physical activity, we used the Croatian version of International Physical Activity Questionnaire-Short Form for the last 7 days[27,28]. Total physical activity was calculated as a sum of moderate, vigorous physical activity and walking.

Perceived physical fitness was measured with one item: "How would you rate your physical fitness?" ranging from 1 (very poor fitness) to 10 (excellent fitness)[29]. Perceived self-rated health (SRH) was assessed using one-item question: "How would you rate your health status?" with five possible answers arranged on a Likert scale: (1) very poor, (2) poor, (3) fair, (4) good and (5) excellent[30]. Perceived socioeconomic status (SES) was assessed using one item question: "How would you rate your socioeconomic status?" with three possible answers on a scale of 1-3: (1) below average, (2) average, (3) above average. Perceived self-rated quality of life (SRQOL) was assessed using one item question:" How would you rate your quality of life?" with five possible answers arranged on a Likert scale: (1) very poor, (2) poor, (3) fair, (4) good and (5) excellent.

Statistical analysis

All the data were analyzed in STATISTICA software version 14.0 (Tibco Software Inc., Palo Alto, CA, USA) and G*power version 3.1.9.7. Data are presented as mean (SD) or median (lower-upper quartile) for data measured on a Likert type scale as well as the IPAQ variables according to IPAQ scoring protocol[31]. The associations between gait speed with physical fitness and physical activity were analyzed using univariate and multivariate regression analysis. Univariate regression analysis was performed 3 times (separately for each independent variable associated with gait speed in Model 1). Multivariate regression analysis was performed to analyze simultaneous associations between independent variables and gait speed before (Model 2) and after adjusting for age and BMI (Model 3). Outliers greater than ± 3 SD were rejected in the multivariate regression analysis.

Before the analysis we tested the models for multi-collinearity using the Variance Inflation Factor (VIF); normality of residuals with histogram of residuals and normal probability plot and homoskedasticity with standardized residuals vs. predicted plot. In all the models the calculated VIF was <10 which suggests there is no multi-collinearity. Durbin-Watson test indicated there was no autocorrelation of the residual. All the other assumptions were met for all the models. We calculated the sample size needed for the regression analysis using G*power version 3.1.9.7. We assumed a medium effect size (f^2= .15), alpha level = .05, power= .80 and five predictors. The required sample size was 92 participants. Our sample size exceeded that number and can be considered adequate. Significance was set at P < .05.

Results

Basic descriptive statistics are presented in Table 1 (mean age 19.28 ± .98 years; mean height 166 ± 6.3 cm; mean weight 62.37 ± 11.8 kg; mean BMI 22.68 ± 4.22 kg/m^2). Majority of the participants reported having average socio-economic status (93.43 %), self-rated health (45.45 %), quality of life (51.01 %) and physical fitness (43.43 %).

The associations between physical fitness and physical activity with gait speed are shown in Table 2 and Table 3. In univariate model (Model 1, Table 2), gait speed was associated only with motor fitness (*β*= - .021). In multivariate models, gait speed was also associated only with motor fitness before (Model 2, Table 3, *β*= - .034) and after (Model 3, Table 3, *β*= - .033) adjusting for age and BMI.

Table 1. Basic descriptive statistics of the study participants (n=198).

Variable	Mean (SD)	95% CI	*P*
Age (years)	19.28 (.98)	19.14-19.42	.000
Weight (kg)	62.37 (11.8)	60.72-64.03	.001
Height (cm)	166 (6.3)	165.08-166.83	.000
BMI (kg/m^2)	22.68 (4.22)	22.07-23.25	.000
SES (a.u.)	2 (2-2) *	2.03-2.1	.000
SRH (a.u.)	4 (3-4) *	3.52-3.73	.000
SRQOL (a.u.)	3 (3-4) *	3.46-3.65	.000
SRPF (a.u.)	5 (4-7) *	5.28-5.71	.000
Physical fitness			
Standing broad jump (cm)	154.52 (22.6)	151.26-157.6	.504
4×10 shuttle run test (s)	13.48 (1.13)	13.33-13.64	.018
Gait time 4 meters (s)	2.42 (.24)	2.39-2.45	.294
Gait speed (m/s)	1.67 (.17)	1.64-1.69	.002
Height-normalized gait speed (s^{-1})	1.01 (.10)	.99-1.02	.043
Physical activity	**Median (lower - upper quartile)**	**95 % CI**	***P***
VPA (MET-min/week)	0 (0-960)	570.51-894.54	.000
MPA (MET-min/week)	480 (0-960)	642.33-957.06	.000
Walking (MET-min/week)	1757.25(924-2772)	1767.49-2114.84	.000
Total physical activity (MET-min/week)	2961 (1485-4638)	3125.63-3821.15	.000

Note: BMI - body mass index; SES - socioeconomic status; SRH - self-rated health; SRQOL - self-rated quality of life; SRPF - self-rated physical fitness; VPA - vigorous physical activity; MPA - moderate physical activity; PA - physical activity; * - denotes using median (lower - upper quartile); *P* – Shapiro-Wilk test for normality (*P*-value).

Table 2. The relationship between physical fitness and physical activity variables with gait speed, univariate regression analysis.

Variables	Model 1 – Dependent variable : Gait speed				
	β (95 % CI)	*β**	*SE β* *	*t*	*P*
Standing broad jump	.000 (-0 to 0)	.04	.072	.553	.581
4×10 m SRT	-.021 (-.04 to -0)	- .143	.071	-2.026	.044
Total PA	.000 (-0 to 0)	.02	.072	.278	.781

Note: *β*- *β* unstandardized regression coefficient; *β** - β standardized regression coefficient; *SE β* * - the standard error for the standardized beta; CI – confidence interval.

Table 3. The relationship between physical fitness and physical activity variables with gait speed, multivariate regression analysis.

Variables	**Model 2 – Dependent variable: Gait speed** R^2= .028; *Adjusted* R^2= .013 $F(3.193)$=1.88; P=.134 *VIF*=5.1					**Model 3 – Dependent variable: Gait speed** R^2= .066; *Adjusted* R^2= .042 $F(5.191)$=3.44; P=.022 *VIF*=7.55				
	β (95 % CI)	β*	*SE* β*	*t*	*P*	β (95 % CI)	β*	*SE* β*	*t*	*P*
Standing broad jump	- .001 (-0 to 0)	- .13	.101	-1.24	.214	-.001 (-0 to 0)	-.19	.10	-1.79	.075
4×10 m SRT	- .034 (-.06 to -0)	- .23	.102	-2.29	.023	-.033 (-.06 to -0)	-.22	.1	-2.24	.026
Total PA	.000 (-0 to 0)	.00	.072	-.06	.95	.000 (-0 to 0)	.03	.072	.46	.643

Note: R^2 – the coefficient of determination; *Adjusted* R^2 – the adjusted coefficient of determination; *VIF* – Variance Inflation Factor; β- β unstandardized regression coefficient; β* - β standardized regression coefficient; *SE* β * - the standard error for the standardized beta; CI – confidence interval.

Discussion

The main purpose of this study was to determine the associations between physical fitness and physical activity with gait speed in young adults. Our study shows: (1) physical activity was not significantly associated with gait speed and (2) only motor fitness but not muscular fitness was associated with gait speed in young adults both before and after adjusting for age and body-mass index.

The average gait speed of the participants in our study was 1.67 m/s which is higher than 1.44 m/s shown in Israeli women[32]. Another study from the USA showed an average gait speed of 1.37 m/s[33] which is like 1.38 m/s in young women from Australia[34] but it is worth noting that both studies used somewhat different methodology to measure gait speed. Furthermore, the usual gait speed of Swedish (1.24 m/s) and especially Kuwaiti (1.08 m/s) women of the same age is lower than the value obtained in our study, although in the mentioned research the sample was rather small (n=15 per group) and a different methodology to measure gait speed was used[35]. The studies used gait mats or walkways[33,35], body markers[24] and automatic timing methods[34] to measure gait speed which could be one of the reasons for different gait speed values obtained comparing to the ones in our study. Young Canadian adults[36] show a gait speed of 1,28 m/s measured on a treadmill and Tunisian young male adults[37] show an average gait speed of 1,23 m/s measured with motion cameras and reflective markers. A meta-analysis by Bohannon and Williams Andrews[38] shows an average gait speed of 1.34 m/s for women aged 20-29 which is also lower than the value obtained in our study. In a study from the USA that used almost identical methodology to ours a notably lower gait speed of 1.11 m/s in women aged 18-29 (n=179) was obtained[26]. The only difference in the methodology is that the study mentioned used a static start to measure gait speed in contrast to a dynamic start in our study. Dynamic starts compared to static starts are associated with higher gait speed considering the possibility of accelerating before timing of the gait starts[39]. Even the gait speed values of participants from the same country and region tend to differ. Those differences suggest that gait speed is a highly individualized trait of a person's gait.

When evaluating gait speed with a stopwatch, a certain degree of variability that can influence results should always be considered. Results show an expected measurement error of .004 to .008 m/s for a stopwatch measurement[40]. Also, single investigator timing could introduce systemic bias to overestimate gait speed. Specifically, gait speed measured by a stopwatch seems to be significantly higher compared to the results obtained by wearable sensors[41]. Contrary, some studies show there is no significant difference of gait speed measured with a stopwatch and an automated timing system[39]. Frequent use of the mentioned test may help to overcome those obstacles in research settings. Furthermore, gait speed measured by different researchers compared to automated timing of gait speed can differ significantly[42]. To make sure it does not happen, in our study only one researcher measured the gait speed of all the participants. Nevertheless, when it is possible, automated timing techniques are recommended to measure usual gait speed to control the influence of the researcher[26].

Our results of no significant association between PA and gait speed are contrary to the previous findings. Specifically, a study in young adults has shown results opposing to ours with gait speed being associated with PA[43]. It is important to emphasize that in comparison to our study, Niang & McFadyen[43] used Baecke Questionnaire of Habitual Physical Activity to assess PA levels, and their sample consisted of only 16 men aged between 22 and 44. Studies on older adults also show a significant association between high levels of PA and walking ability expressed as gait speed[18]. It is known that lack of PA in older adults is related to a decrease in endurance and muscle strength[44] that can lead to falls. Although PA was not associated with gait speed in our sample of young female adults, it is necessary to promote PA in this population considering the decline in PA that could be somewhat described by the changes in daily life of university students who are leaving their home to attend university[45]. What is furthermore worrying is that using a self-report questionnaire usually leads to over-reporting of physical activity. The true levels of PA are even lower than the ones reported. Compared to the accelerometer data, the overestimation is usually in the range of 36 to 173 percent with the mean overestimation of 106 percent[46]. Although over-reporting of PA by IPAQ-SF remains to be the key limitation of self-reported measures of PA[47], questionnaires are most often used in studies of physical activity due to their feasibility, easy administration and low cost. Nevertheless, there is a need for a standardized approach in reporting PA so that the results can be compared across multiple studies.

Significant association between motor fitness and gait speed was found in previous studies in older adults[20,48]. Agility and dynamic balance are fundamental for performing safe movements in everyday life. Previous studies have indicated the efficacy of agility and dynamic balance degradations in predicting the decline in walking ability[49]. Older adults with type-2 diabetes show improvements in gait speed after undergoing a 6-week high intensity functional training program[50]. For that reason, interventions targeting those with a lowered gait speed should aim to enhance agility and dynamic balance to ensure a sufficient level of physical functioning is sustained to overcome everyday tasks. Although the regression coefficients of motor fitness have shown to be significantly related to gait speed, this relationship was not very strong. The whole models (2 & 3) explained only up to 6.6 percent of the variance in gait speed. Therefore, more parameters, such as cardiorespiratory fitness, flexibility, speed, coordination and confounders such as training history and overall injury history should be added in the future analysis to develop better models explaining a higher portion of gait speed variance.

Our study found that lower limbs muscle fitness was not associated with usual gait speed, which was not expected considering the characteristics of motions during walking. Contrary to our study, in a sample of older adults there is a significant association between lower limbs muscle strength and gait speed[20,22,48,51]. Although it is worth noting that different physical fitness tests are used to determine fitness levels in the elderly population of which the Senior Fitness Test battery is most used. Intervention studies in older adults show a significant improvement in physical fitness and gait speed after a 10-week exercise program of 3 days per week[52]. On the same note, studies in young female adults show that after a 12-week exercise intervention enhancing muscular fitness, there is also an improvement in gait speed[53].

This study has several limitations. First, by using a cross-sectional design we cannot conclude the causality of the association. Second, we used subjective measures to assess PA which often leads to an overestimation of PA. Third, for the gait speed measurement, a stopwatch was used that could influence the results making the gait speed significantly higher than it is and using more objective methods of measurement could produce somewhat different results. Also, by including more variables such as cardiorespiratory fitness, flexibility, speed, coordination and adding more confounding variables such as training history and overall injury history into the models, different values of regression coefficients would be obtained and possibly a higher coefficient of determination, making the whole model stronger. Furthermore, longitudinal research could provide insights into how the changes in physical fitness might alter gait speed in young adults. Finally, our study included only female participants and by including male participants, associations might have been different and generalizability for both sexes could have been made.

Practical Applications

Physical activity and physical fitness levels in the student population are dropping. Identifying those with low levels of physical fitness is important for maintaining their health and designing interventions to delay any future muscle impairment and gait abnormalities. Interventions should include designing programs to enhance physical fitness levels in young adults and using leisure time to further enhance physical activity levels.

Conclusions

This study analyzed the association between physical activity and physical fitness with usual gait speed. Our results demonstrated a significant association only between motor fitness and usual gait speed. However, our findings should be taken with caution considering our limited sample size and the fact that all the participants were female students attending the same faculty.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in this study.

Ethical Committee approval

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Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

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