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# The Relationship Between Pedometer Step Counts and Estimated $VO_2$Max as Determined by a Submaximal Fitness Test in Adolescents

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The purpose of this study was to examine the relationship between pedometer step counts and estimated $VO_2$max as determined by a submaximal exercise test. Participants ($N = 115$; 65 girls, 50 boys) wore pedometers for five days and completed the Queen's College Step Test (QCST). Based on these results participants were classified as HIGH, MOD, or LOW cardiorespiratory fitness. Boys accumulated more steps per day ($p < .05$) than girls (12,766 ± 4,923 versus 10,887 ± 2,656). The relationship between estimated $VO_2$max and mean steps/day was moderate ($r = .34$, $p < .01$). Participants classified as having HIGH fitness levels accumulated more steps/day than LOW-fit adolescents ($p < .05$). The results from this study suggest that estimated $VO_2$max as determined by a submaximal exercise test is moderately associated with mean steps/day in adolescents.

Participation in regular physical activity is associated with a variety of positive health outcomes for young people (41). Higher levels of physical activity during youth are associated with good mental health (31), improved self-esteem (12) and an improved profile for a number of health risk behaviors (32). While many of the physiological benefits of physical activity are difficult to establish in youth (9), a physically active lifestyle during this period is associated with a reduced risk for numerous lifestyle diseases, including type II diabetes and cardiovascular disease (4,48,34). In addition to these benefits, researchers have hypothesized that physical activity levels in youth influence cardiorespiratory fitness. However, studies examining this relationship have produced equivocal results (37,5).

A number of possible explanations have been offered to account for the poor associations found between cardiorespiratory fitness and physical activity among youth. First, cardiorespiratory fitness has a strong genetic component (7) and adaptive responses to training will vary between individuals (3). Second, the activity patterns of youth are sporadic (50) and it has been suggested that few children and

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adolescents achieve the volume or intensity of activity necessary for the development of cardiorespiratory fitness (1). Finally, many of the inconsistent findings can be explained by physical activity measurement issues (13). The majority of studies examining the relationship between physical activity and cardiorespiratory fitness have used self-report measures of physical activity (e.g., 6,25). The measurement of physical activity among youth using self-report is problematic (50), and most self-report measures have low to moderate associations with objective measures of physical activity (20). While social desirability may lead individuals to overestimate their physical activity, studies have found that children and adolescents underestimate the amount of time they spend in activity of low to moderate intensity physical activity (42,35).

Recent studies have assessed the relationship between physical activity and cardiorespiratory fitness among youth using objective measures of physical activity. Gutin and colleagues (15) examined the association between cardiorespiratory fitness (multistage treadmill test) and 5 days of accelerometry and found cardiorespiratory fitness was associated with both moderate ($r$ =.30) and vigorous physical activity ($r$ = .45). In another study using accelerometry, accumulated vigorous physical activity was significantly correlated (boys $r$ = .51 and girls $r$ = .52) with total laps in the multistage fitness test (26). Le Masurier and Corbin (22) examined the relationship between cardiorespiratory fitness (multistage fitness test) and 6 days of pedometer monitoring in a sample of 223 adolescents. They found the relationship between step counts and cardiorespiratory fitness to be moderate ($r$ = .35) and concluded that the fittest middle school students were also the most active. Rowlands, Eston and Ingledew (37) examined the relationship between aerobic fitness and physical activity in children and found that accelerometry ($r$ = .66) and pedometry ($r$ = .59) were both associated with fitness levels.

The measurement of physical activity using objective measures has helped to clarify and more accurately represent the relationship between physical activity and cardiorespiratory fitness (22). However, studies assessing the relationship between cardiorespiratory fitness and objective measures of physical activity have generally used maximal testing methods such as the multistage fitness test (22, 15). While these tests provide a valid and reliable measure of cardiorespiratory fitness, they require adolescents to provide maximal effort. There is continued debate regarding the place of fitness testing in schools (8), and numerous studies have demonstrated that adolescents perceive fitness testing in a negative way (17,11,23). For example, Hopple and Graham (17) found that many students devised strategies to avoid participating in the mile-run test. Consequently, the results from maximal fitness tests might reflect level of motivation as much as level of cardiorespiratory fitness. For this reason, we hypothesized that a cardiorespiratory fitness test requiring a submaximal effort may be perceived more positively than a maximal test and help to clarify the relationship between physical activity and cardiorespiratory fitness in adolescents. To the researchers' knowledge, no previous study has examined the relationship between pedometer-determined physical activity and estimated $VO_2$max from a submaximal fitness test in adolescents. An additional aim of this study was to identify pedometer determined levels of physical activity in a sample of Australian adolescents. Few studies have examined the physical activity patterns of Australian adolescents using objective measures. One recent study examined the physical activity behavior of adolescents using 7 days of pedometry

(16). However, the study involved a different population and the authors used an unsealed pedometer protocol.

# Method

## Participants

Ethics approval for the study was obtained from the University of Newcastle, New Wales (NSW), Australia and the NSW Department of Education and Training ethics committees. Participants (mean age = 14.15 ± .76 years) were a subsample of students recruited for a school sport study. Eight schools (six government schools and two independent schools) were invited to take part in the original study and from this number, six schools consented to participate (five government schools and one independent school). From the study population of 140 students, 115 students (82% completion rate) completed the Queen's College Step Test (QCST) to provide an estimate of cardiorespiratory fitness testing. No student refused to complete the QCST and the missing 18% were because of absence on the day of testing or failure of the heart rate devices. The pedometer monitoring was part of the baseline measures of the overall study and the QCST was conducted as a weekly activity in one of two health and fitness centers used in the study.

## Measures

Pedometers are simple small electronic devices clipped to a belt or worn on the hip that detect vertical oscillations, providing a total of movements displayed as steps (30). Pedometers are unobtrusive, inexpensive, and offer a good estimate of physical activity if most body movements occur in the vertical plane such as walking, jumping, running, and skipping (28). They are, however, insensitive to nonlocomotor forms of movement (e.g., resistance training), unable to record the magnitude of the movement, and do not possess real-time data storage capabilities (43). The Yamax SW701 pedometer was used in this study to measure physical activity because it is one of the most accurate and reliable pedometers commercially available (40). Yamax pedometers have good convergent validity, demonstrated by their high correlations with oxygen consumption ($r$ = .81) and Caltrac accelerometer counts ($r$ = .99; 14). All pedometers used in the current study were checked for calibration by research assistants using the walking test recommended by Tudor-Locke and Myers (45). Of the 150 pedometers checked, only two pedometers exceeded 5% error.

The QCST was used to provide an estimate of cardiorespiratory fitness. The QCST is a simple method for establishing maximum aerobic power and is a valid and reliable measure (27). Chatterjee and colleagues (10) compared results from a $VO_2$max test and the QCST and found that results for the submaximal step-test were strongly correlated ($r$ = .95) with $VO_2$max scores in young males.

## Procedure

Participants were asked to wear sealed pedometers for 5 days. This included 4 consecutive school days and 1 weekend day. Previous research has established that 4 days of monitoring using an objective measure are necessary to provide a reliable estimate of habitual physical activity (36,44). On the first morning of monitoring, students were instructed on how to attach the pedometers (at the waist on the right hand side) by a research assistant and asked to remove the pedometers only when sleeping or when the pedometer might get wet (e.g., swimming, surfing, showering). During the first testing session, pedometers were sealed with stickers and students were reminded not to tamper with the devices. At school each morning research assistants removed the stickers, recorded the scores, reset the devices and returned the pedometers to the students. Students were asked if they had removed the pedometer for more than 1 hour during the day. In accord with previous studies using pedometers to measure activity (22,49), the daily step data of students who removed their pedometers for more than 1 hour were excluded ($n = 12$) and replaced with the average of remaining days. Research assistants were instructed to not reveal daily step counts to students.

The step tests were completed in the weeks immediately following the step monitoring. Before starting the QCST, students attached POLAR® heart rate monitors (model number FS1) and receivers (Kempele, Finland) to display their heart rates. The 3-min QCST was performed on a bench (41 cm high) and the cadence for the step test was established using a metronome. The metronome was set at 88 beats per minute (BPM) for females and 96 BPM for males. Before starting the test, students practiced the rhythm using the following step sequence; left up/right up, left down/right down—each movement was performed during a single metronome beat. Before starting the test, students were given a short rest and heart rate monitors were checked. The standard procedure of the QCST is for the subject to remain standing for 5 s after completing the test and have their pulse recorded at the carotid artery for a 15 s count. To reduce measurement error, heart rate monitors were used to record heart rate (HR) in the 15 s period following the test. HR was recorded by a research assistant 10 s after completing the test, then again at 15 s and 20 s. The average of the three scores was taken and the following equations were used to predict maximum oxygen uptake capacity (27):

$$\text{Girls: } VO_2\text{max } (\text{mL} \times \text{kg}^{-1} \text{ max} \times \text{min}^{-1}) = 65.81 - 0.1847 \times \text{heart rate BPM}$$

$$(r = \text{-}.76, \text{ SEE} = \pm\ 2.9 \text{ mL})$$

$$\text{Boys: } VO_2 \text{ max } (\text{mL} \times \text{kg}^{-1} \times \text{min}^{-1}) = 111.33 - 0.42 \times \text{heart rate BPM}$$

## Data Treatment

Based on findings from previous research (36), pedometer scores below 1,000 steps and above 30,000 steps were deleted and treated as missing data. In the current study, four participants had pedometer step readings above 30,000. Students who had completed at least 4 days of pedometer monitoring, including one weekend day, were included in all analyses. However, to determine the relationship between mean steps/day and estimated $VO_2$ max and number of monitoring days, separate bivariate correlations were calculated for the first 2 days of monitoring, the first 3 days of monitoring and 4 days or more. Eighty-five students completed 4 days or more of pedometer monitoring, 17 students wore pedometers for 3 days and 13 students provided only 2 days of pedometer data.

Estimated $VO_2$max calculated from heart rate recovery from the QCST was used to provide a measure of cardiorespiratory fitness. In accord with previous studies (19,22), students in the lowest quintile (20%) of cardiorespiratory fitness were grouped in the low fitness category (LOW), the students in the next two quintiles (40%) were categorized as having moderate fitness (MOD) and students in the top two quintiles (40%) were classified as having high fitness levels (HIGH). The same process was applied when the data file was split by gender.

## Statistical Analyses

All statistical analyses were completed using SPSS version 14.0 software and alpha levels were set at $p < .05$. All variables were checked for normality and satisfied the criteria. Intraclass correlation coefficients (ICCs) were calculated for 2 days (1 and 2), 3 days (1–3) and 4 days (1–4) to determine the reliability of the physical activity data. As no step recommendations for Australian youth currently exist, proportions of students meeting the U.S. step (33) and BMI-referenced estimates (46) were reported. Independent samples $t$ tests were used to determine if gender differences existed for cardiorespiratory fitness and mean steps/day. ANOVA was used to examine the differences in mean steps/day among individuals with HIGH, MOD and LOW fitness levels. In this model, mean steps/day was the dependent variable and cardiorespiratory fitness group was the independent variable. A Bonferroni post hoc procedure was then used to determine where the differences existed. Additional analyses were conducted for boys and girls separately.

Pearson bivariate correlations with two-tailed tests of significance were calculated to determine the relationship between cardiorespiratory fitness and mean steps/day (first 2 days, first 3 days, and 4 days). Additional analyses were calculated for boys and girls separately (4 days of monitoring only). Cohen's $f^2$ ($f^2 = R^2/1—R^2$) was used to calculate effect sizes for the relationship between steps/day and estimated $VO_2$ max for boys and girls separately. To control for gender differences, gender and $VO_2$max (independent variables) were entered into a hierarchical regression model explaining mean steps/day (dependent variable).

# Results

The majority of participants were born in Australia (95%) and spoke English at home (89%). The ICCs (95% confidence intervals) for mean steps/day were .60 (.43–.73) for 2 days, .71 (.60–.79) for 3 days and .79 (.72–.85) for 4 days. Physical activity and $VO_2$ max estimates (means and standard deviations) are reported in Table 1. Boys accumulated significantly more steps/day ($M$ = 12,766, $SD$ = 4,923) than girls ($M$ = 10,887, $SD$ = 2,656) $F(1,83) = 19.42$, $p < .05$ (based on 4 days of monitoring). Forty nine percent of boys and 52% of girls achieved the U.S. step recommendations of greater than 13,000 and 11,000 steps/day, respectively. Approximately one third of students satisfied the BMI-referenced standards (15,000 and 12,000 steps/day for boys and girls, respectively). Boys $VO_2$max scores ranged from 31.5 to 60.1 $mL·kg^{-1} · min^{-1}$ and girls' scores ranged from 30.0 to 40.7 $mL·kg^{-1} · min^{-1}$. Boys ($M$ = 47.4 $ml·kg^{-1} · min^{-1}$, $SD$ = 7.6) achieved higher $VO_2$max estimates than girls ($M$ = 34.8 $ml·kg^{-1} · min^{-1}$, $SD$ = 2.5), $F(1,83) = 43.14$, $p < .001$.

Results of the ANOVA (cardiorespiratory fitness level × mean steps/day) indicated that there was a main effect for fitness level, $F(2,82) = 3.72$, $p < .05$ (Figure 1). The Bonferroni post hoc procedure indicated that participants in the HIGH fitness category accumulated significantly more steps/day than participants in the LOW category ($p > .05$). There were no statistically significant differences between the HIGH and MOD categories ($p = .16$) or between the LOW and MOD

**Table 1 Means and Standard Deviations for Steps/Day and Cardiorespiratory Fitness**

| Variable | Total (*N* = 115) | Boys (*n* = 50) | Girls (*n* = 65) |
|---|---|---|---|
| Estimated $VO_2$max (mL·kg$^{-1}$ · min$^{-1}$) | 40.9 (4.4) | 47.4 (7.6) | 34.8 (2.5) |
| Mean steps/day (first 2 days) | 11,250 (4,401) | 11,798 (5,487) | 10,847 (3,323) |
| Mean steps/day (first 3 days) | 11,161 (4,145) | 11,806 (5,039) | 10,588 (3,005) |
| Mean steps/day (4 days) | 11,793 (4,005) | 12,766 (4,923) | 10,887 (2,656) |

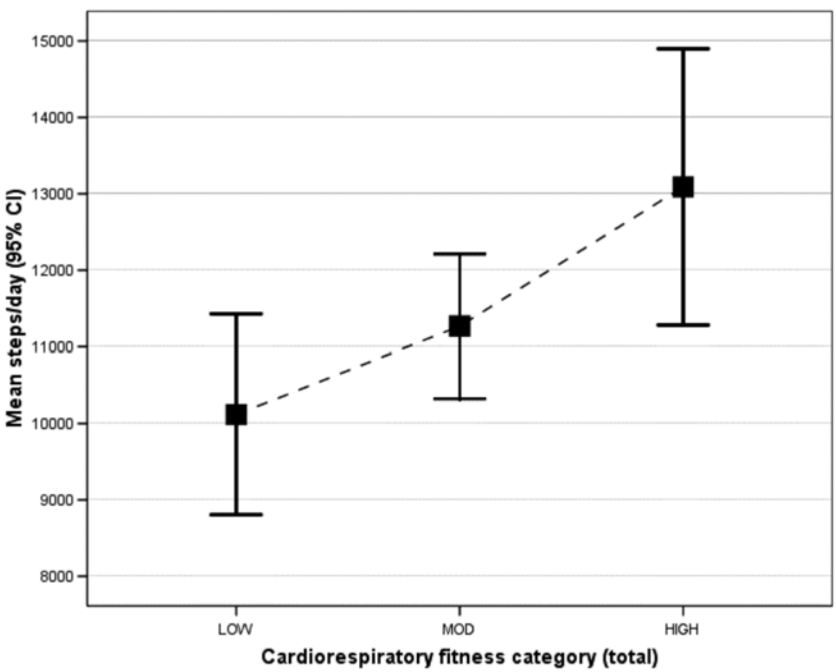


**Figure 1** — Mean steps/day (95% CI) for participants grouped by cardiorespiratory fitness category.

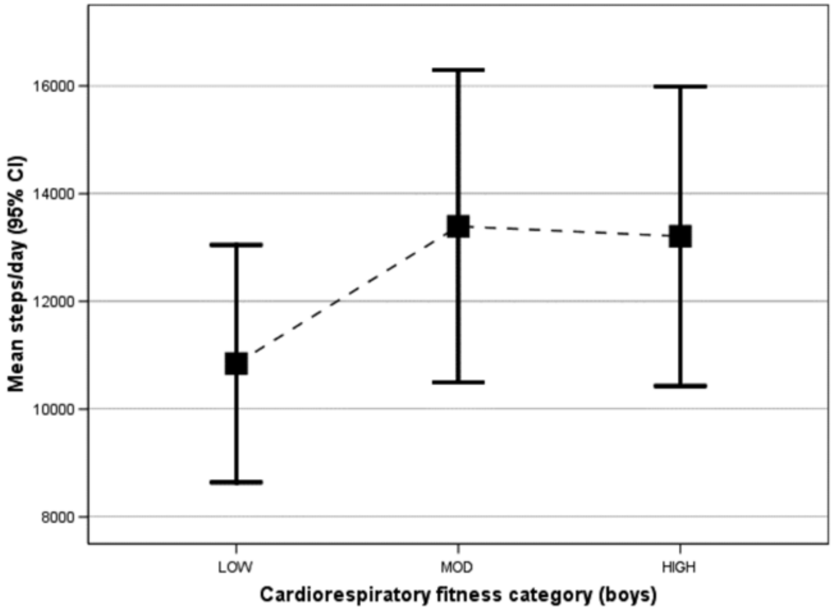


**Figure 2** — Mean steps/day for boys grouped by cardiorespiratory fitness category.

categories for mean steps/day ($p$ = 1.00). When the analyses were stratified by gender, no statistically significant differences were found between the fitness categories for boys [$F$(2,38) = .67, $p$ = .52] (Figure 2) or girls [$F$(2,41) = 1.35, $p$ = .27] (Figure 3).

The relationship between estimated $VO_2$max and mean steps/day was examined using Pearson's bivariate correlation. Correlations were calculated between mean steps/day and cardiorespiratory fitness for the average of the first 2 days, the first 3 days and 4 days of monitoring. The correlation between mean steps/day and estimated $VO_2$max for the first 2 days was not statistically significant ($r$ = .18, $p$ = .06). The correlation coefficient between the first 3 days of monitoring and estimated $VO_2$max was statistically significant ($r$ = .23, $p$ < .05). A moderate correlation was found between 4 days of data and estimated $VO_2$max ($r$ = .34, $p$ < .01). In the first step of the regression model predicting mean steps/day, gender (β = -.24, $p$ > .05) explained 4% of the variance [$F$(1,83) = 4.88, $p$ < .05]. Estimated $VO_2$max (β = .38, $p$ < . 05) explained an additional 5% of variance in mean steps/day [$F$(2,82) = 5.37, $p$ < .05].

When the data were stratified by gender, the relationship between estimated $VO_2$max and mean steps/day was not significant for boys ($r$ =.29, $p$ = .07). However, based on Cohen's $f^2$, this was a medium-sized effect ($f^2$ = .09). The relationship was not statistically significant for girls ($r$ = .11, $p$ = .48) and the effect size was small ($f^2$ = .012).

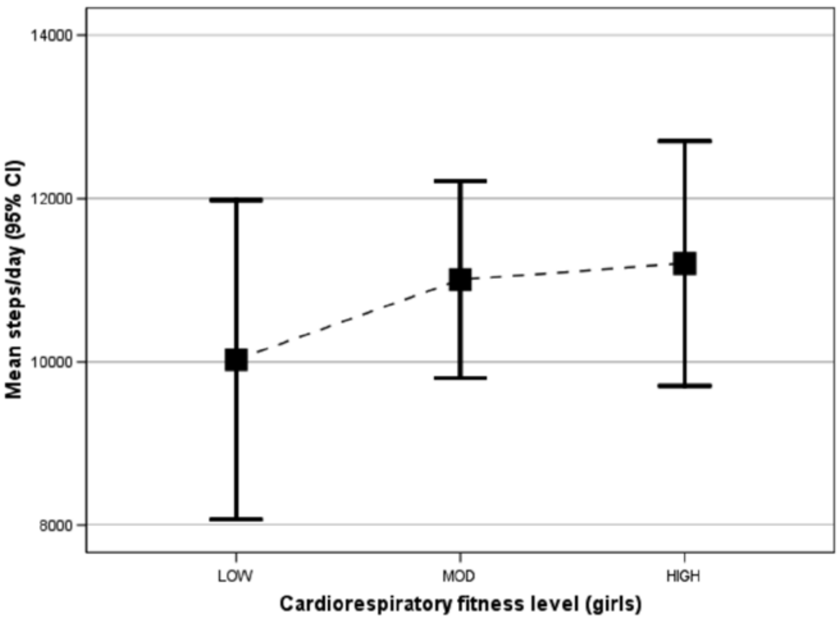


**Figure 3** — Mean steps/day for girls grouped by cardiorespiratory fitness category.

# Discussion

The aim of this study was to examine the relationship between pedometer-determined physical activity and cardiorespiratory fitness from a submaximal fitness test. This study confirmed that students with higher aerobic fitness levels recorded on average, more steps per day than individuals with lower fitness levels. The current study was unique because physical activity was measured using pedometers and cardiorespiratory fitness was measured using a submaximal fitness test. Although the relationship between cardiorespiratory fitness level and mean steps/day was only moderate ($r$ = .34), the findings from this study provide some useful implications for future studies.

While numerous researchers have hypothesized that activity levels should be predictive of fitness levels in youth populations, studies examining this relationship have provided equivocal results (29,47). In the current study, the relationship between estimated $VO_2$max and mean steps/day was stronger for boys ($r$ = .29) than for girls ($r$ = .11). This finding corresponds with some studies (47,6), but not all (22). Hussey and colleagues (18) found that estimated $VO_2$max (multistage fitness test) was inversely related to vigorous physical activity ($r$ =−.10) in girls and directly related to physical activity among boys ($r$ = .22). Alternatively, Le Masurier and Corbin found similar correlations between pedometer steps and cardiorespiratory fitness for boys ($r$ = .31) and girls ($r$ =.30). In the current study, the range of $VO_2$max scores for girls was very small and few girls achieved high $VO_2$max estimates. One possible explanation for the higher levels of cardiorespiratory fitness in boy is that they are typically more active than girls and their physical activity is often more vigorous in nature (39).

Research has established that fitness testing is perceived in a negative way by many adolescents (23,11), which might impact upon the effort that individuals exert during maximal fitness testing sessions. While it is not known if submaximal tests are viewed in a more positive light, it was hypothesized that adolescents would perceive a submaximal fitness test more favorably than a maximal test. However, little is know about student attitudes and motivation to maximal and submaximal fitness testing methods and future research should explore this relationship.

While the use of submaximal tests has measurement limitations, there are also a number of benefits to using these measures with adolescents. First, the QCST has good validity and reliability and in a recent study, predicted $VO_2$max from the QCST was strongly correlated with $VO_2$max ($r = .95$) in young males (10). Second, submaximal measures like the QCST can be completed by most participants as long as they adhere to the stepping pace. Finally, there is no overt public scoring of test results and participants cannot determine the level of fitness achieved by others. For these reasons the QCST might be more appealing to adolescents.

This study provides additional information regarding the number of days required to provide a reliable estimate of physical activity. The ICC reliability coefficients for 1–2 days, 1–3 days, and 1–4 days of monitoring were .60, .71, and .79, respectively. Previous studies have found higher reliability coefficients in child (30) and youth samples (21). For example, Le Masurier and colleagues found ICC values of .90 for 4 days of monitoring, increasing the interindividual variability. The lower reliability coefficients identified in the current study might be because of the inclusion of at least 1 weekend day of monitoring. Another possible explanation is reactivity to pedometers, as participants were aware that their activity levels were being measured (49). Considering both possibilities, it is not surprising that the relationship between cardiorespiratory fitness and mean steps/day increased as the number of monitoring days increased. The strongest association was found between 4 days of monitoring, even though the sample size had decreased to 85 participants.

An additional aim of this study was to identify levels of pedometer-determined physical activity in a sample of Australian adolescents. Consistent with previous studies of adolescent pedometer-determined activity (36,30), males recorded higher step counts than females. However, when the students' scores were compared with existing step estimates, similar proportions of boys and girls met the recommendations (approximately 50% of boys and girls; 33). Although BMI was not measured in the current study, only 30% of students achieved the BMI-referenced estimates of 12,000 steps/day for girls and 15,000 steps/day for boys (46).

Limitations of this study include the inclusion of only 1 weekend day of monitoring and the surrogate measures of physical activity and fitness. Researchers have identified that more monitoring days are required to provide a reliable estimate of habitual physical activity when weekend days are included in the assessment period (36,44). In this study, participants were required to wear a pedometer for 4 weekdays and 1 weekend day. As mentioned previously, the inclusion of 1 weekend day may have contributed to the lower reliability coefficients found in this study.

The findings of this study are limited by measurement issues, as previous research has demonstrated that the size of the relationship between physical activity and additional variables will depend upon the measures used (38). Although pedometers offer a good estimate of physical activity if movements occur in the vertical plane, they are insensitive to nonlocomotor movement, are unable to detect intensity and cannot be worn in water-based activities and some contact sports (44). Despite the advantages of using submaximal fitness tests with adolescents, laboratory tests that measure actual $VO_2$max are considered the gold standard for measuring cardiorespiratory fitness (2,24). In addition to these limitations it should be noted that the current study is cross-sectional in nature and causality cannot be determined.

In conclusion, this study indicates that students with higher fitness levels as determined by a submaximal test, are more physically active than students with low levels of cardiorespiratory fitness. An overall moderate relationship between mean steps/day and estimated $VO_2$max was found in the current study. While the correlation coefficients identified in this study are weaker than some previous studies that have used objective measures of physical activity, the relationship between pedometer-determined physical activity and estimated $VO_2$max from a submaximal test has not been previously studied.

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