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Sleep and Exercise Behaviors Do Not Differ Based Upon Aerobic Capacity or Hand Grip Strength

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ABSTRACT

Background: Despite the known benefits of physical activity (PA), most of the population in the United States fails to meet minimum recommended levels, and this lack of activity is believed to affect their health and well-being. **Objective:** The purpose of this study was to compare lifestyle behaviors of exercise and sleep in low, moderate, and high performers for maximal aerobic capacity (VO_2max) and hand-grip strength (GS). **Methods:** Participants (n = 107, 19-62 years old) performed physical fitness assessments: estimated VO_2max through submaximal cycle ergometry, and GS. Physical activity (PA) and sleep were assessed via self-reported questionnaires: physical activity as a vital sign (PAVS) and the Pittsburgh Sleep Quality Index (PSQI). Participants were categorized according to age and gender-specific normative values as low, medium, and high performer (LP, MP, and HP). Group characteristics were compared for each ranked variable using Kruskall-Wallis tests. **Results:** PAVS scores revealed 66.3% (n=68) of participants met minimum PA of 150 min/week (221.6 ± 177.8). According to VO_2max performance groups, the LP group was taller, heavier, had higher diastolic blood pressure, and had a larger waist circumference than MP or HP (p =.000-.029), with moderate and high effect sizes. When categorized by relative GS, the LP group was heavier and had larger waist and hip circumferences than the HP group (p =.003-.011), all with high effect sizes. **Conclusion:** Despite high levels of self-report PA in this cohort, this did not translate to better cardiorespiratory fitness or muscular strength. Participants met PA guidelines but achieved suboptimal scores for VO_2max and GS signifying elevated risk of mortality. The incongruity between PA levels and fitness classification suggest that lifestyle habits may not be a suitable surrogate for objective measurement of fitness.

Key words: Cardiorespiratory Fitness, Hand Strength, Physical Fitness, Risk Reduction Behavior

INTRODUCTION

Physical activity (PA) and associated physical fitness (PF) are important modifiable factors in determining health and longevity. Regular PA is strongly associated with reduced morbidity and mortality in a broad variety of medical conditions when recommended levels of PA are achieved or exceeded (Arem, Moore, Patel, et al, 2015). However, an estimated 80% of adults in the United States fail to meet recommended levels of PA (Piercy et al., 2018). Identifying how lifestyle factors influence a person's total amount of PA and PF could be an area for targeted intervention.

Although PA and PF are similar, they are not interchangeable. PF represents the objective and specific measurement of an individual's ability to perform PA encompassing a spectrum of characteristics that are activity dependent (DeFina et al., 2015). Measurement of PF allows for assessing level of performance and charting progress over time for comparison to recommended guidelines or to normative ranges. The American College of Sports Medicine (ACSM) PA guidelines recommend targeting both cardiorespiratory fitness and muscular fitness domains, with total weekly exercise meeting or exceeding 150 total minutes of moderate-intensity exercise with two or more days of resistance training (Piercy et al., 2018; Riebe, 2018). Cardiorespiratory fitness can be modified with regular PA, and has been shown to lower mortality and is an important factor in preventing or slowing the development of metabolic syndrome and type 2 diabetes mellitus (Kodama, Saito, Tanaka, et al, 2009). Maximal oxygen uptake (VO_2max) is commonly measured via maximal or submaximal exercise tests as a representation of cardiorespiratory fitness (Kaminsky, Arena, & Myers, 2015).

In addition to cardiorespiratory fitness, upper extremity strength and endurance have also proven beneficial (Kim et al., 2018). Bohannon (2015) has suggested that hand-grip strength (GS) is an important measure of overall strength and also has an association to overall health, comorbid status, and physical function across healthy and clinical populations. GS is highly correlated with knee extension strength

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in adults, suggesting the utility of this measure as an overall indicator of muscular fitness (Bohannon, Magasi, Bubela, Wang, & Gershon, 2012). VO_2max and GS each have an inverse relationship with all-cause and cardiovascular mortality, but the combination of high cardiorespiratory fitness and high GS may prove to be a greater predictor of mortality (Kim et al., 2018; Stenholm et al., 2014).

Regular performance of PA is necessary for improving PF, and has been shown to be a more important determinant of VO_2max than sedentary time (Pollock, Duggal, Lazarus, Lord, & Harridge, 2018). Various methods of assessing PA are available, though measuring PA as a vital sign (PAVS) is supported in clinical situations (Cowan, 2016; Golightly et al., 2017). PAVS includes self-reporting two metrics of PA: 1) the number of days in the previous week where PA was performed that increased heart rate and breathing above normal and 2) the average number of minutes such activity is performed (Golightly et al., 2017). This metric is simple and quickly assesses a person's PA without regard to the type of activity chosen. A third, optional question asks about self-reported number of days per week engaged in muscle strength training. PAVS has been shown to have criterion validity with accelerometry (Ball et al., 2015) and good agreement with the previously validated Modifiable Activity Questionnaire (Ball, Joy, Gren, & Shaw, 2016).

In addition to PA, sleep is an important contributor to health and, when impaired, has been associated with increasing obesity, hypertension, type 2 diabetes mellitus, and cardiovascular disease (St-Onge et al., 2016). The Pittsburgh Sleep Quality Index (PSQI) is a valid and reliable tool utilized in identifying sleep quality in both clinical and non-clinical populations (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989; Mollayeva et al., 2016). Higher PSQI scores, indicating worse sleep patterns and habits, have been associated with impaired health-related quality of life in young adults, regardless of body composition and fitness level (Franquelo-Morales et al., 2018). The relationship of sleep to health and quality of life may suggest that restorative actions could be as important as the physical acts such as cardiorespiratory and muscular fitness.

GS and VO_2max have been used to predict risk of morbidity and mortality. However, very little information is available on the association between healthy lifestyle behaviors and these metrics. The purpose of this study was to compare lifestyle behaviors of PA and sleep in individuals with low, moderate, and high cardiorespiratory fitness and muscular strength as measured by VO_2max and GS respectively.

METHODS

Study Design and Participants

This was an observational study that included 107 participants (46 females and 61 males) between the ages of 19-62. There was no investigator or participant blinding, nor was there any randomization of participants in this study, as all participants completed an identical series of tasks during the study. Eligibility required participants to be between 18 and 70 years of age and cleared to perform PA according to the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Warburton, Bredin, Jamnik, & Gledhill, 2011). If any participants were taking medications that influenced heart rate (e.g. beta blockers) or were not cleared to perform PA according to the PAR-Q+, they were excluded from the study. Participants were recruited using convenience sampling methods. Participants were requested to refrain from ingesting food, alcohol, caffeine, and using tobacco products at minimum three hours prior to the start of the session.

Participants completed a university-approved informed consent and were asked to report: age, sex, activity level, and complete the PAR-Q+, PAVS, and PSQI. The PSQI was used to evaluate participants' sleep quantity and quality. Participants answered questions regarding their sleep habits over the previous month. The PSQI was evaluated using the standard scoring instructions that accompany the instrument. A standard biometric screening included height and body mass gathered using a stadiometer and calibrated scale. Heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were assessed after the participant rested for five minutes in a relaxed seated position. Waist circumference was measured at the smallest point between the xiphoid process and the umbilicus; hip circumference was measured at the widest point between the umbilicus and pubis. Assessments were done in the same order for each participant.

Cardiorespiratory Fitness

A submaximal cycle ergometer test was conducted to estimate VO_2max. Participants warmed-up for three minutes at zero load, followed by four, three-minute stages with a gradual increase in load for each stage. Participants were instructed to maintain 50 rotations/minute throughout the testing session. The testing protocol for each participant was determined based on their weight and self-reported activity, obtained during pre-participation screening (Table 1). Table 2 shows the testing procedures for each protocol. Throughout the test, heart rate (HR) was monitored using a Polar chest strap (Kempele, Finland) and recorded once each minute. Participants were not allowed to advance in the testing protocol until a steady-state HR, defined as two consecutive HR measurements at the end of a stage within 6 bpm of each other was met. The rating of perceived exertion (RPE) was taken at the end of each stage, using the 6-20 scale. Participants completed all four stages (12 minutes of exercise) or stopped when: 1) they reported an RPE of 17 or more; 2) their HR reached 80% of their age-predict-

Table 1. Conditions for selecting the appropriate cardiorespiratory protocol

Protocol selection criteria		
Body weight in kg (lbs)	**Active-No**	**Active-Yes**
< 73 (160)	A	A
74-90 (161-199)	A	B
>91 (200)	B	C

A, B, and C refer to the three different protocols in Table 2

Table 2. Three submaximal exercise protocols for assessing cardiorespiratory fitness via cycle ergometry at 50 rpm

	Test Protocol		
Stage	**A**	**B**	**C**
1	150 kgm/min (.5 kg; 25 W)	150 kgm/min (.5 kg; 25 W)	300 kgm/min (1.0 kg; 50 W)
2	300 kgm/min (1.0 kg; 50 W)	300 kgm/min (1.0 kg; 50 W)	600 kgm/min (2.0 kg ;100W)
3	450 kgm/min (1.5 kg; 75 W)	600 kgm/min (2.0 kg; 100 W)	900 kgm/min (3.0 kg; 150W)
4	600 kgm/min (2.0 kg;100 W)	900 kgm/min (3.0 kg; 150 W)	1200 kgm/min (4.0 kg; 200 W)

A, B, and C are the three different submaximal exercise protocols used

ed maximal HR; 3) they requested to stop; or 4) any other adverse event occurred (e.g. feeling dizzy). After completion, participants completed a five-minute cool-down with no resistance. During this cooldown, HR was documented every 30 seconds for the first two minutes and blood pressure was recorded after two minutes. VO_2max was estimated by plotting submaximal HR against load for each stage and extrapolating to estimated maximal HR to estimate maximal load and aerobic capacity (Riebe, 2018).

Hand-grip Dynamometry

Each participant completed three GS measurements on both the dominant and nondominant hands using a Jamar handgrip dynamometer (Lafayette Instrument, Lafayette, IN) following the protocol as reported by Beam (2014). This was done by alternating the testing hand each trial with 30 seconds of rest provided between assessments. The grip size was adjusted per manufacturer standards so that the middle segment of the middle finger laid perpendicular to the dynamometer. Participants were instructed to hold their elbow in a comfortable position between 90 and 180 degrees, and squeeze with maximum effort. The highest measured value from each hand was then used for data analysis. The two values were added together and divided by body mass to calculate relative GS (Beam & Adams, 2014).

Statistical Analysis

Participants were placed into groups: high performer (HP), moderate performer (MP), and low performer (LP) according to gender and age normative values for relative GS and VO_2max (Beam & Adams, 2014; Canadian Society for Exercise Physiology., 2003; Kaminsky et al., 2015). Cardiorespiratory fitness HP corresponded with estimated VO_2max within 65-99th percentile, MP within 25-65th percentile, and LP below 25th percentile according to Kaminsky et al (2015). GS HP corresponded with "well above average" or "above average," MP with "average," and LP with "below average" or "well below average" according to Beam (2014).

Means and standard deviations were calculated for each group. Cronbach's alpha was calculated for PAVS to ensure reliability of this tool. Group characteristics for height, age, resting hemodynamics (HR, SBP, DBP), PAVS, and PSQI were compared using Kruskal-Wallis tests—one for each ranked variable: estimated VO_2max and relative GS. A non-parametric test was selected because the data violated assumptions for normality and homogeneity as shown with a Shapiro-Wilks test. Pairwise comparisons were conducted pending main effect significance. Cohen's *d* effect sizes and 95% confidence intervals (CIs) were calculated for any pairwise significant differences. Effect sizes were interpreted as follows: ≥ 0.8 is large, < 0.8 to > 0.2 is moderate, and ≥ 0.2 is small. An alpha level of 0.05 was used to determine statistical significance. Non-parametric analysis and pairwise comparisons were conducted in SPSS 24.0 (IBM, Aramonk, NY). Effect sizes were calculated using Microsoft Excel (Redmond, WA).

RESULTS

A total of 107 participants (32.6 ± 12.9 years old, 171.56 ± 10.26 cm, 78.2 ± 16.9 kg) completed all surveys and exercise tests. Waist and hip circumference measurement mean values were 84.8 ± 12.1 cm and 98.9 ± 9.0 cm respectively. Resting cardiovascular measurements were 75.7 ± 11.4 bpm for HR, SBP of 123.9 ± 12.4 mmHg, and DBP of 77.8 ± 7.3 mmHg. Global PSQI mean was 3.89 ± 2.49 for the entire cohort. The mean estimated relative VO_2max for the cohort was 31.0 ± 10.2 ml/kg/min.

PAVS revealed that participants engaged in 4.1 ± 1.7 days/week of moderate/vigorous exercise, 50.6 ± 28.0 min/day of PA, and 221.6 ± 177.8 min/week of PA. The recommended 150 min/week of PA was achieved by 63.6% (n = 68) participants. The Cronbach's alpha for PAVS responses was high at 0.97. Strength training was reported an average of 2.4 ± 1.8 days/week, with 66.4% (n = 71) of participants achieving the recommended two days/week.

No difference was identified in PAVS or PSQI for VO_2max or GS when individual participants were categorized as low, moderate, or high performers. There was large variation in the number of minutes/day and minutes/week of participation in moderate/vigorous exercise within each performance group.

Cardiorespiratory Fitness

Twenty-one participants (19.6%) were classified as HP, 16 participants (15.0%) were classified as MP, and 69 participants (64.5%) were classified as LP according to the VO_2max estimation. One participant was removed from analyses because their VO_2max could not be estimated using the same plot method as the other participants. Analyses revealed that the groups were different in height ($p < 0.001$), body mass ($p < 0.001$), DBP ($p = 0.004$), SBP ($p = 0.007$), waist circumference ($p < 0.001$), and hip circumference ($p = 0.029$). The descriptive statistics and details of the pairwise comparisons are shown in Table 3 and Figure 1. Of note, the LP group was taller and with greater body mass than the other two groups, with high effect sizes. The LP group also had a significantly higher DBP than both other groups, and a higher SBP than the HP group, with moderate effect sizes. Lastly, the LP group also had a larger waist circumference than the other two groups with a high effect size, and a higher hip circumference than the HP group, with a moderate effect size. There was no difference noted between the MP and HP groups for any of the variables assessed. There was also no difference among groups for physical activity participation as shown in Figure 1.

Hand-grip Dynamometry

For relative GS, there were 63 participants (58.9%) in the LP group, 26 participants (24.3%) in the MP group, and 18 participants (16.8%) in the HP group. Analyses revealed significant group differences for mass (p = 0.011), waist circumference (p = 0.009), and hip circumference (p = 0.003). The pairwise comparisons showed that the LP group had greater body mass, larger waist circumference, and larger hip circumference than the HP group, all with high effect sizes. Descriptive statistics for these variables are shown in Table 4.There was no difference among groups for physical activity participation as shown in Figure 1.

DISCUSSION

The purpose of this study was to compare lifestyle behaviors of exercise and sleep in low, moderate, and high performers of VO_2max and GS. Statistical analyses revealed no difference between these lifestyle behaviors across performance levels. Analyses did demonstrate differences between performance groups for both VO_2max and GS. Generally, the

Table 3. Mean and SD for grouping by VO_2max performance

	LP (n=69)	MP (n=16)	HP(n= 21)	Effect Size (95% CI)
Age (yrs)	31.3±11.9	32.9±13.7	35.3±14.3	
Height (cm)	175.2±9.2†‡	166.6±6.6*	163.0±9.8*	LP/MP: .98 (.41, 1.53) LP/HP: 1.31 (0.77, 1.82)
Mass (kg)	84.8±16.4 †‡	67.6±10.5*	63.9±8.0*	LP/MP: 1.11 (.53, 1.67) LP/HP: 1.40 (.86, 1.92)
HR (bpm)	77.2±11.6	71.6±10.2	75.1±10.6	
SBP (mm Hg)	125.8±13.0‡	121.8±12.6	118.6±8.4*	LP/HP: .59 (.09, 1.09)
DBP (mm Hg)	79.4±6.5†‡	74.1±10.2*	75.2±6.2*	LP/MP: .42 (-.13, .97) LP/HP: .36 (-.14, .84)
Waist (cm)	88.5±12.3†‡	78.1±8.9*	77.1±6.9*	LP/MP: .88 (.32, 1.44) LP/HP: 1.01 (.49, 1.51)
Hip (cm)	100.2±9.6‡	97.9±9.0	94.9±4.7*	LP/HP: .61 (.11, 1.10)
Global PSQI	4.17±2.65	3.63±2.13	3.38±2.06	
VO_2max (ml/kg/min)	25.6±5.3	34.3±4.3	46.5±8.7	

*indicates significantly different from Low Performer (LP), †indicates significantly different from Moderate Performer (MP), ‡indicates significantly different from High Performer (HP), p<0.05. Effect sizes and 95% CI are shown for statistically significant pairwise comparisons. Abbreviations: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), Pittsburgh Sleep Quality Index (PSQI), maximal aerobic capacity (VO_2max)

Table 4. Mean and SD for grouping by relative GS performance

	LP (n=63)	MP (n=26)	HP (n=18)	Effect Size (95% CI)
Age (yrs)	34.4±14.5	31.0±9.4	29.0±10.6	
Height (cm)	171.9±10.4	172.7±11.7	168.9±7.1	
Mass (kg)	81.6±18.2‡	76.6±14.1	68.6±11.8*	LP/HP: .76 (.22, 1.29)
HR (bpm)	77.3±11.9	74.1±11.4	72.7±9.1	
SBP (mm Hg)	123.7±14.3	123.5±8.5	125.2±10.3	
DBP (mm Hg)	77.9±8.2	78.8±5.2	76.1±6.8	
Waist (cm)	88.0±12.9‡	81.6±9.7	78.7±9.2*	LP/HP: .76 (.22, 1.29)
Hip (cm)	101.2±9.3‡	96.7±7.8	94.0±6.7*	LP/HP: .82 (.27,1.35)
Global PSQI	4.00±2.75	3.80±2.29	1.81±3.90	
Hand Grip (kg/kg)	0.92±0.20	1.24±0.16	1.82±0.50	

*indicates significantly different from Low Performer (LP), †indicates significantly different from Moderate Performer (MP), ‡indicates significantly different from High Performer (HP), p<0.05. Effect sizes and 95% CI are shown for statistically significant pairwise comparisons. Abbreviations: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), Pittsburgh Sleep Quality Index (PSQI)

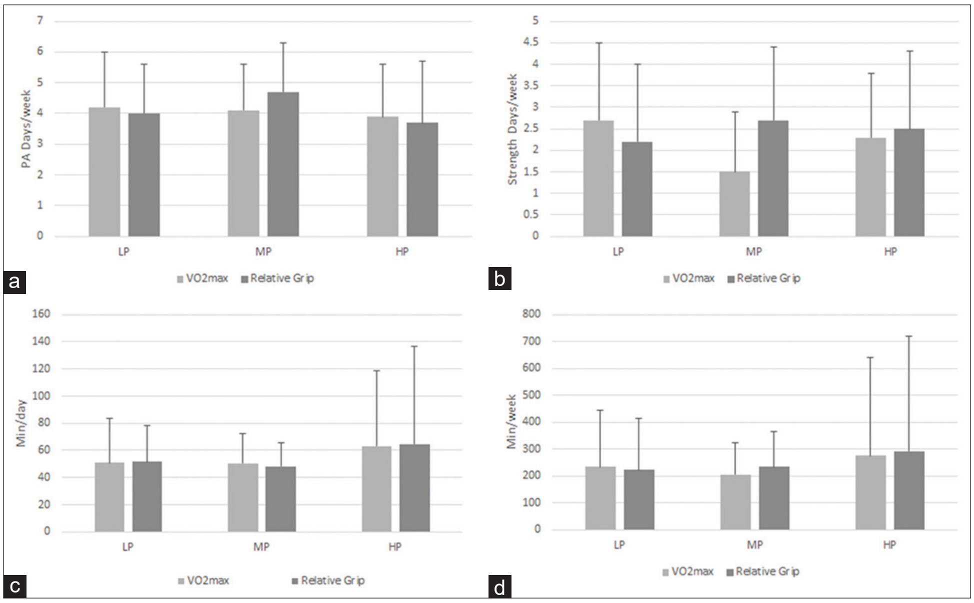

Figure 1. Comparison of physical activity participation by VO2max and relative GS performance categories. a) Number of days/week of participation in moderate/vigorous exercise, b) Number of days/week of participation in strength training, c) Number of minutes/day of participation in moderate/vigorous exercise, d) Number of minutes/week of participation in moderate/vigorous exercise. LP = Low Performer, MP = Moderate Performer, HP = High Performer

LP group for both objective measures demonstrated larger anthropometrics, and resting blood pressure. These findings are consistent with the expectation that LP participants would exhibit less optimal results in these categories than more physically fit individuals.

The sample of participants in this current study were more active with 63.6% and 66.4% meeting recommended PA levels for total PA min/week and days/week of resistance training respectively, compared to an estimated 20% of the US population (Piercy et al., 2018). Adherence to moderate/vigorous PA guidelines reduce morbidity and mortality and are supplemented through strength training activities twice weekly for all individuals (Leitzmann, Park, Blair, & al, 2007; Piercy et al., 2018). Most participants in this study achieved recommended PA levels, suggesting that they are engaging in a sufficient amount of PA to lower morbidity and mortality risk. However, this is an assumption, because they were unsuccessful in achieving high levels of fitness as determined by estimated VO_2max and GS testing. The incongruence between PA levels and VO_2max or GS fitness classification in this sample suggests that lifestyle PA habits may not be a true surrogate for PF measures (DeFina et al., 2015). This disagrees with previous literature suggesting that PF correlates with participation in running, walking, jogging, leisure-time activity, age, and frequency of sweating (Kohl, Blair, Paffenbarger, Macera, & Kronenfeld, 1988). Further, participants may have believed they were achieving high levels of PF based upon their active lifestyles and achieving the PA recommendations. Previous literature has shown that individuals have a misperception of their own fitness levels and tend to believe they are more fit than they really are (Wells, Avery, Eschbach, & Bunn, 2016).

Positive associations between sleep and physical activity participation have been noted in epidemiological studies (Youngstedt & Kline, 2006). The acute and chronic effects of exercise have been shown to improve sleep (Shapiro & Bachmayer, 1988; Urponen, Vuori, Hasan, & Partinen, 1988). Like cardiorespiratory fitness, sleeping 7-8 hours is associated with reduced risk of morbidity and mortality (Chennaoui, Arnal, Sauvet, & Leger, 2015). Thus, the combination of these two healthy habits—exercise and sleep—would likely result in improved overall health and well-being. The current study evaluated differences in sleep quality, as measured by the PSQI, between low, moderate, and high performers for cardiorespiratory fitness and GS. In both cases, HP groups tended to have higher PSQI scores than the other groups, indicating worse sleep quality. However, the PSQI scores range from zero (no difficulty with sleep) to 21 (poor sleep quality), and the scores represented in this study are all very low. Thus, there was likely too little variation in the PSQI scores to make conclusions about the importance of sleep quality with PF.

In general, across the two PF measures, individuals within the LP category appear to taller, heavier, and with larger waist and hip measurements than higher performing individuals. With respect to VO_2max, LP individuals had higher SBP and DBP than HP participants, as anticipated. Both GS and VO_2max were calculated relative to body mass, so a higher body mass would negatively impact participants in these PF measures. Individuals with higher levels of cardiorespiratory fitness may have the lowest levels of long-term mortality; but exercise and lifestyle modifications resulting in increases of VO_2max from LP to MP or HP, have also shown benefits in all-cause mortality (Ehrman et al., 2017). But these data show that there was no difference in exercise habits between these performance groups. Thus, while assessing participation in exercise and PA are important, an objective measurement of VO_2max may be more useful and provide more clarity about risk of disease and death than self-reported PA in categorizing overall PF.

There were several limitations to this study. First, this study assessed a disease-free population, and does not represent associations that may be found in populations with orthopaedic or other chronic health conditions. Also, the tasks selected are ones that may not be regularly included in average workout regimens. While GS has been shown to have good correlation with upper extremity functional strength (Bohannon et al., 2012), it remains an estimation of, and not conclusive for, global muscular fitness. Additionally, PA was assessed via self-reported statistics that may have been unduly influenced, consciously or unconsciously, by the participant's knowledge that they were participating in research. An attempt to control this bias was made by allowing participants to complete necessary paperwork without direct oversight by examiners and without examiners communicating directly with the participants about these statistics. Lastly, and as mentioned previously, this was a convenience sample of individuals surrounding a university community. As noted previously, 63% of participants in this study met or exceeded the weekly exercise recommendation, well above the 20% achieved nationally. Though the direct comparisons in this study are made against the participants themselves rather than population normative values, the disparity between the national average PA and this sample may limit generalizability.

CONCLUSION

Self-reported PA levels may not represent PF when classified by performance standards. PAVS may be a strong initial screening tool for assessing individual PA, but it does not seem to adequately capture PF measures of VO_2max and GS performance. Objective measurement of PF should be conducted when attempting to identify risk for morbidity and mortality. The incongruence between PA levels, cardiorespiratory fitness and GS classification in this sample suggest that lifestyle PA habits may not be a true surrogate for PF measures (DeFina et al., 2015).

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