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Dose-response between pedometer assessed physical activity, functional fitness and fatness in healthy adults aged 50-80 years.

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Running Head: Dose-response of physical activity

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Objectives: This study examine dose-response relationships of walking with multiple aspects of physical function and measures of body fatness in apparently healthy, independent adults aged 50-80 years.

Methods: 201 adults (81 male, 120 female) aged 50-80 years underwent assessment of body mass index (BMI), Body fatness, waist circumference (WC) and 6 measures of functional fitness. Sealed pedometery, worn over 7 days, was used to determine physical activity (PA). PA was categorized into 3 groups (low=2501-5000, medium=5001-7500, and high=>7501 steps/day).

Results: Results from a series of 2 (gender) X 3 (PA dose) ways analysis of covariance (ANCOVA), controlling for age indicated dose-response effects of PA for all functional fitness tests where participants classed as High PA had higher scores for arm curl, chair stand, 6 minute walk, back scratch and sit and reach and lower scores for timed up and go test compared to those classed as Low and Medium PA. There were also significant main effects for PA dose for BMI, WC, and body fat %. Those classed as low PA had significantly higher BMI, WC and body fatness compared to those classed as medium and high PA.

Conclusions: This study shows a positive dose-response trend whereby as an individual undertakes more daily steps (based on previously established step-count groups), multiple aspects of functionality increase and anthropometric markers of overweight and obesity decrease.

Keywords: Obesity; Ageing; Sarcopenia; Exercise

Introduction

The world population is becoming increasing older (United Nations, 2005) and such a large scale demographic has far reaching implications for public health and quality of life in older adulthood (Reinhardt, 2003). Understanding how health enhancing behaviours impact on physical function and body fatness is an important first step in establishing effective preventive measures to enhance older adults' health.

Age related loss of muscle mass and strength, termed sarcopenia, has been cited as one of the key public health issues in the older adult population as it results in reduced mobility, loss of independence, higher risk of falls and reduced quality of life (Montero-Fernandez et al., 2013). Age related loss of muscle mass is compounded by age related infiltration of fat into muscle which also leads to loss of physical function (Visser et al., 2005) and increased body fatness is associated with decreased physical function as age increases (Bouchard et al., 2009). As a consequence, understanding effective means to offset sarcopenia, reduce overfatness and cost effective means to maintain health and offset age-related declines in physical function are a public health priority.

Participation in physical activity (PA) has protective effects on multiple facets of health in older adults including cardiovascular disease and its related comorbidities (Luuk and Pihl, 2003), age-related cognitive decline (Kramer, et al., 1999), functional limitation (Bouchard, et al., 2011) and body fatness (Bouchard, et al., 2011). However, estimates suggest that only 20% of the older adult population are sufficiently active for health benefits (Hansen et al., 2012; Metzger et al., 2008) and that the average amount of moderate to vigorous physical activity decreases at a rate of 1 minute/day between the ages 65-85 (Hansen et al., 2008).

Walking is the most common form of activity/exercise in older adults, despite the decreases in physical activity seen with increasing age, as it is readily available and can be engaged in as part of everyday life (Sherwood and Jeffery, 2000). Despite this, there is uncertainty regarding the beneficial relationships of walking volume on physical functioning, especially when evaluating the impact of dose (increasing walking volume) – response (changes in physical functioning) in older populations (Dondzila et al., 2015). Recently, Dondzila et al (2015) demonstrated a dose-response relationship with walking volume and self-reported physical function and 6 minute walk test (6MWT) performance in a sample of American older adults. In their study, there was a graded relationship whereby high PA was associated increased 6MWT distance and self-reported physical functioning. The present study sought to act on the subsequent recommendations of Dondzila et al (2015) by investigating whether such dose-response relationships exist with other aspects of functionality and anthropometric measures in a sample of older adults. Furthermore, while most prior work has tended to focus on adults aged 60 years or older, the present study examined adults aged 50-80 years. This was purposeful as comparatively little is known about time course and transition to sarcopenia (Murphy et al., 2013) and age related changes in muscle mass, strength and performance is said to occur form 50 years of age (Lindle et al., 1997, Lynch et al., 1999, Janssen et al., 2000). Understanding changes in physical functioning from this age onwards may have significance in terms of older adult quality of life (Lynch et al., 1999) and the decade 50-60 may be an important window for the development of effective interventions to ameliorate changes in physical functioning as a consequence of ageing in older adulthood (Lindle et al., 1997, Lynch et al., 1999, Janssen et al., 2000). The aim of this study was to examine dose-response relationships of walking with multiple aspects of physical function and measures of body fatness in apparently healthy, independent adults aged 50-80 years.

METHODS

Participants

Following institutional ethics approval and written informed consent, 201 independent, community-dwelling adults aged 50-80 years (81 male, 120 female, mean age ± SD = 66.1 ± 7.7 years) were recruited from local community groups within the city of Coventry, UK in 2015. Prior to participation, each participant completed a health history questionnaire to record past and present health conditions. Exclusion criteria were the following: registered blindness, severe hearing impairment uncontrolled hypertension or diabetes, symptomatic cardiorespiratory disease, severe renal or hepatic disease, uncontrolled epilepsy, progressive neurological disease, chronic disabling arthritis or any musculoskeletal condition which prohibited physical activity/exercise. Participants who were currently taking beta blockers of calcium ion channel blockers were also excluded from taking part.

Procedures

Anthropometric Measures and Body Fatness

Body mass, measured to the nearest 0.1kg and height, to the nearest 1mm were assessed barefoot with participants wearing light clothing using a Seca Stadiometre and Weighing scales (Seca Instruments, Germany, Ltd). Body mass index (BMI) was then determined as kg/m^2. Waist circumference (WC, cm) was assessed using an anthropometric measuring tape at the level of the umbilicus at the end of gentle expiration. Body fatness (%Fat) was determined using leg to leg bioelectrical impedance analysis (Tanita BF-350, Tanita Inc, Japan). Participants adhered to recommended guidelines for accurate assessment of body fatness using bioelectrical impedance analysis including no drinking for 4 hours prior to the test, no exercise for 12 hours prior to the test, urination 30minutes prior to the test, and no alcohol consumption for 48hours before the test (Heyward, 1991).

Assessment of Physical Function

Physical Function was assessed using Rikli and Jones (1999) Senior Fitness Test, comprising the: 6MWT, 8Foot Timed Up and Go (TUG), Arm Curl (AC), Chair Stand (CS), Back Scratch (BS) and Chair Sit and Reach (SAR) test. All procedures followed those described previously for administration of the Senior Fitness Test (Rikli and Jones, 2001). The TUG comprised the number of seconds required to get up from a seated position, walk 8 feet, turn, and return to seated position. For AC the number of bicep curls that were completed in 30 seconds holding a hand weight of 2.27kg for females and 3.63kg for males was recorded. The CS test comprised the number of full stands that could be completed, from a seated position, in 30 seconds with arms folded across the chest. The BS tests was completed for both the right and left sides where one hand reached over the shoulder with the other up the middle of the back. Distance (cms) between extended middle fingers was assessed and the average of right and left sides was taken as an overall measure. The SAR was completed from a sitting position at the front of a chair with one leg extended and hands reaching towards toes with the distance (cms) between extended fingers and tip of toe being assessed. The average of right and left sides was taken as an overall measure of flexibility. For the 6MWT participants were instructed to walk as quickly as possible for 6 minutes up a down a 20m walkway marked off in 2m segments, and were informed that they could slow down or rest if necessary. Standardised encouragement was given each minute during the tests. The distance walked was recorded and used for analysis.

Assessment of Habitual Physical Activity

Habitual physical Activity (PA) was determined using a sealed, piezo-electric pedometer (New Lifestyles, NL2000, Montana, USA) worn over seven days. Prior to the monitoring period, participants were familiarized with the pedometers and were briefed as to the nature of their involvement in the study. During familiarisation, the participants were instructed on pedometer attachment (at the waist), its removal (only during showering/bathing, swimming or sleeping), and reattachment on waking each morning. Participants were asked not to tamper with the pedometer and to go about their normal activities during the monitoring period. The model of pedometer employed in the study shows good validity and has been found to be highly accurate (Crouter, Schneider, & Bassett, 2005). Daily step counts were stored in the internal memory of each pedometer enabling recall of each day's step count on collection of each pedometer. Across the period of measurement, the participants were asked to complete a pedometer log to verify that the pedometers were worn for the entire time of the study. The average steps/day values was then segmented into four groups to characterise walking behaviour; < 2500steps/day, 2501-5000 steps/day, 5001-7500 steps/day and >7500 steps/day, as used by Donzila et al (2015) when examining the dose-response of walking behaviour with 6MWT distance in older adults. However, in the current study no participants recorded average daily step counts of <2500 steps/day, leaving data characterised into 3 groups: low PA (2501-5000 steps/day), medium PA (5001-7500 steps/day) and high PA (>7500 steps/day).

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences Version 20 (SPSS Inc., Chicago, IL, USA) and the alpha level was set at $p < 0.05$ a priori. A series of Analysis of Covariance (ANCOVAs) were used to examine any dose-response effect of walking PA on BMI, WC, %Fat and measures of physical function. Gender and PA category (low, medium, high) were used as between subjects factors and age was employed as a covariate. In this way the analysis was able to determine any effect of gender and PA category on the dependant variables in question whilst at the same time explaining the amount of variance explained for each dependant variable by the covariate of age (Field, 2010). Partial η^2 was also used as a measure of effect size. In all cases backwards elimination to achieve a parsimonious solution was employed.

Results

Anthropometric Variables

Mean ± SE of anthropometric variables split by gender and PA dose are presented in Table 1. Results from ANCOVAs, controlling for age indicated significant gender main effects for gender for BMI (P = 0.0001, Partial η^2 = .075), WC (P = 0.0001, Partial η^2 = .278) and body fat % (P = 0.011, Partial η^2 = .04). Males had higher values for BMI and WC but lower values for body fatness % compared to females. There were also significant main effects for PA dose for BMI (P = 0.0001, Partial η^2 = 0.179), WC (P = 0.0001, Partial η^2 = 0.147), and body fat % (P = 0.0001, Partial η^2 = 0.201). In all cases, those classed as low PA had significantly higher BMI, WC and body fatness compared to those classed as medium and high PA (all P = 0.01 or better). There were no gender X PA dose interactions and nor was age significant as a covariate for any of the anthropometric variables ($P>0.05$).

Physical Function and Physical Activity

Mean ± SE of functional fitness variables split by gender are presented in Table 2. ANCOVA identified significant gender main effects for BS (P = 0.015, Partial η^2 = 0.036) and SAR (P = 0.001, Partial η^2 = 0.151) tests, in all cases females performed significantly better than males. In regard to PA dose, significant main effects were evident for CS (P = 0.001, Partial η^2 = 0.095), AC (P = 0.001, Partial η^2 = 0.168), TUG (P = 0.001, Partial η^2 = 0.095), 6MWT (P = 0.001, Partial η^2 = 0.375), BS (P = 0.001, Partial η^2 = 0.173), and SAR (P = 0.001, Partial η^2 = 0.190).

For all tests other than CS there were significantly poorer values for each test between those classed as low PA and medium PA, low PA and high PA, and medium PA and high PA (all $P>0.05$ or better). For CS there were significantly poorer scores for those classed as low PA compared to high PA (P = 0.002) and those classed as medium PA compared to high PA (both P = 0.001). There was no significant difference in CS scores between those classed as Low PA and medium PA (P = 1.0). Age was significant as a covariate for 6MWT (P = 0.001, β = -2.559) but not for CS, AC, TUG, BS or SAR ($P > 0.05$). This indicated that every 1 year increase in chronological age was associated with decrease of 2.5 metres walked in the 6MWT. In regard to pedometer determined PA, the mean steps/day ± SE undertaken by participants in the current study was 7052.2 ± 204.2. When split by

PA dose the mean steps/day ± SE was 4119 ± 118.1, 6307 ± 118.6 and 7475 ± 201.1 steps/day for low, medium and high PA groups.

Discussion

Although walking is the most common form of PA that older adults engage in, previous research has been equivocal as to the potential protective benefits of walking towards physical function as one progressively attains more steps (Dondzila et al., 2015). The results of the current study show a clear and positive dose-response trend whereby as an individual undertakes more daily steps (based on previously established step-count groups), multiple aspects of functionality increase and anthropometric markers of overweight and obesity decrease. It is key to note that every aspect of physical function that was assessed in the present study showed some form of dose-response where increased PA resulted in improved function. These results extend recent work by Dondzila et al (2015) which reported a dose-response effect of walking for the 6MWT and self-report function in a sample of over 800 older adults. It is also the first to demonstrate such effects in British adults aged 50 years and older. The results of the present study are also supportive of prior work that has shown that increases in walking volume are positively related to numerous health outcomes including body mass index (Tudor-Locke et al., 2008), metabolic syndrome (Park et al., 2008) and quality of life (Yasunga et al., 2006). Moreover, a number of studies have identified increased PA to be associated with 6MWT in older, diseased, adults (Mudge and Stott, 2009).

The population recruited in the present study were apparently healthy, mobile and functionally able and were not selected as representative of the overall older adult population. Rather, this study sought to examine the effect of healthy active ageing who were aged 50-80 years. This decision is congruent with prior work that has sought to examine active ageing (Skelton et al., 1994) as it is important to be able to assess and identify and measure factors limiting functional ability in ageing in those individuals who are apparently healthy and mobile. Given the inclusion/exclusion criteria employed in the present study, the participants might be considered in good health and 'active' and, as such, indicative of what might be expected in an ageing population who are free from any form of hypokinetic disease. Indeed, the mean scores for all of all the physical function tests employed in the present study sat within the 50-60th age and gender specific percentiles as reported by Rikli and Jones (1999). The dose-response responses identified in this study could therefore only be considered representative of an active population. It is however important to establish that such a dose-response exists in a healthy and mobile adult population as a first step to targeting preventive efforts in individuals who are physically able to increase their habitual PA. A useful next step would be to establish whether such a dose-response exists in individuals with very low levels of habitual PA (<2500 steps/day). When physical function tests are considered across low and high PA groups, participants classified as low PA scored in the 10th percentile for 6MWT, BS, SAR and TUG tests and the 25th percentile for AC and CS tests. Conversely those classed as high PA scored between the 75th and 90th percentile for the AC, CS and 6MWT, between the 50th and 75th percentile for SAR, BS and TUG tests based on gender and age specific norms previously reported (Rikli and Jones, 1999).

The present study also recruited individuals from the age of 50 to 80 years on the basis that understanding any changes in physical function from the age of 50 is important in developing effective interventions to enhance physical function with age

(Lindle et al., 1997, Lynch et al., 1999, Janssen et al., 2000). Despite this, few studies have examined the association between objectively assessed walking behaviour and physical function in adults from the age of 50 onwards.

In the current study walking behaviour was grouped using the same method employed by Dondzila et al, which was based on data suggesting that ambulatory estimates for healthy older adults approximate 2000-9000 steps/day (Tudor-Locke, et al., 2011). In the current study the mean steps/day was 7052.2. Consequently, the PA levels of participants in the present study are greater than those reported by Dondzila et al (2015). This is not surprising given the different age ranges used in the present study compared to that of Dondzila et al (2015). It is also important to note that there was a significant relationships between age and average steps/day ($r = -.574$, $P = .001$) in the present study as well as a significant decade by decade decrease in average steps/day ($P = .001$). Mean steps/day ± SE was 9247 ± 317.6, 7537 ± 257.7 and 6016 ± 296.6 for adults aged 50-59, 60-69 and 70-80 years respectively.

Overall, however, the results of the present study might suggest that in strictly healthy and mobile adults aged 50-80 years, decreases in functional performance and increases in fatness may be deferred to an older age and that these positive changes are amplified where habitual physical activity is greater.

There are however some limitations to this study. The cross-sectional design employed makes it difficult to discern causality of PA effects on physical functions. There were also fewer participants in the ‘low’ PA group in the current study compared to the medium and high PA groups. Moreover, pedometry might be considered a limitation in terms of PA assessment as it cannot differentiate mode or intensity of PA. However, pedometers are cost effective tools which accurately capture ambulatory activity. They also offer a methodology which older adults appear to feel more at ease with in terms of procedure engagement and subsequent understanding of the meaning of any PA results obtained. This is important in terms of maximising impact and ensuring clear public health messages from any study of dose-response of PA on health parameters. Without trying to exaggerate the impact of the results presented here, the current study is important for public health in demonstrating the strength of dose-response relationships between ambulatory activity and measures of physical function. The key public health message arising from the current study is that a minimum threshold of 7500 steps/day should be recommended for maintenance of physical function in healthy, independent adults aged 5-80 years and that increases in ambulatory PA above this level will likely result in greater benefit in physical function.

Given the inclusion and exclusion criteria employed in the present study, the results presented here are only indicative of healthy, active adults aged 50-80 years. It may therefore be useful for future research to examine dose-response effects of PA on multiple aspects of physical function in both healthy and diseased older adult populations.

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Conflict of Interest: None

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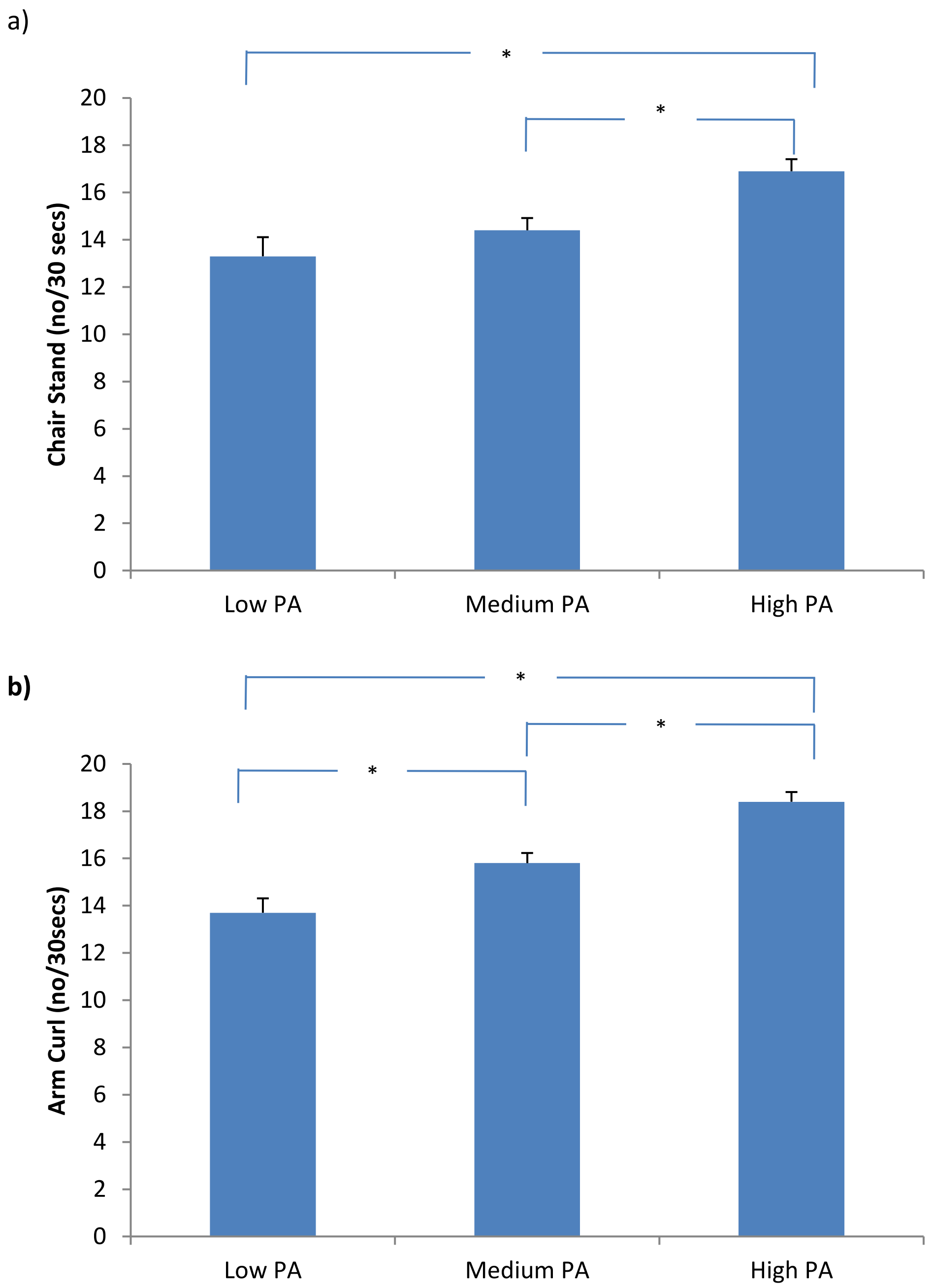
a)

b)



a)
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*
20
18
16
14
12
10
8
6
4
2
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Chair Stand (no/30 secs)
Low PA
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High PA
b)
*
*
*
20
18
16
14
12
10
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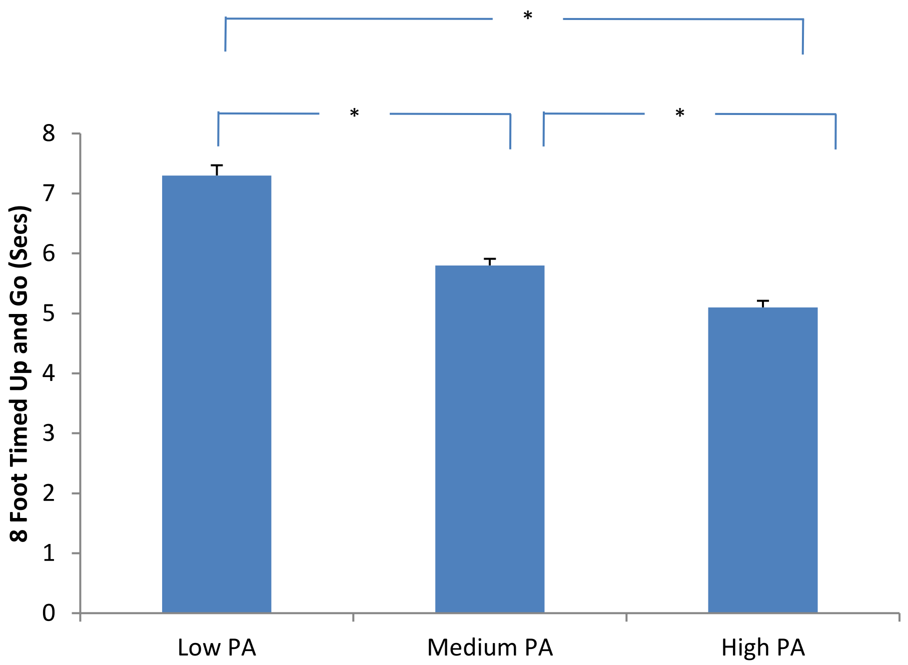
Arm Curl (no/30secs)
Low PA
Medium PA
High PA

c)



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8 Foot Timed Up and Go (Secs)
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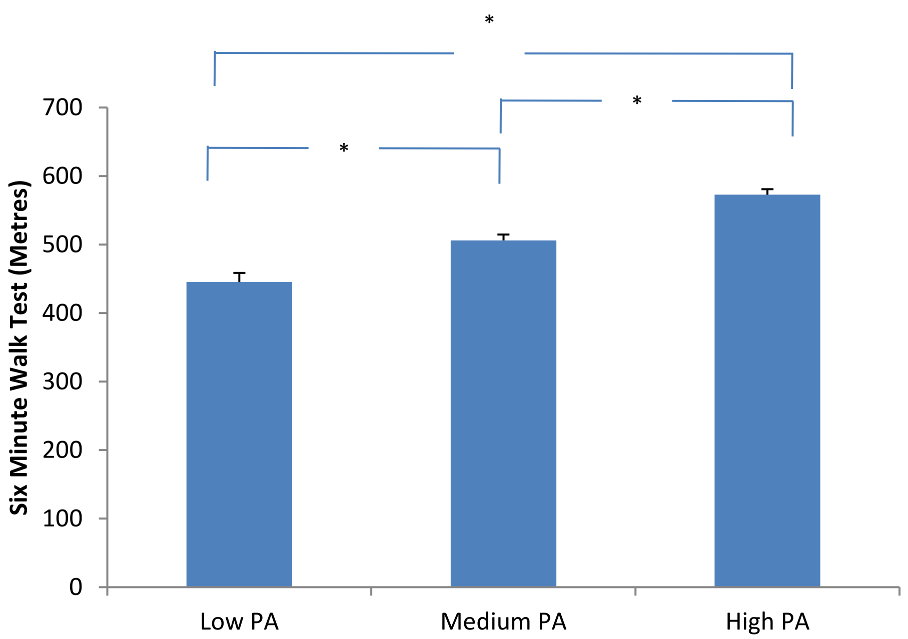
Low PA
Medium PA
High PA

d)



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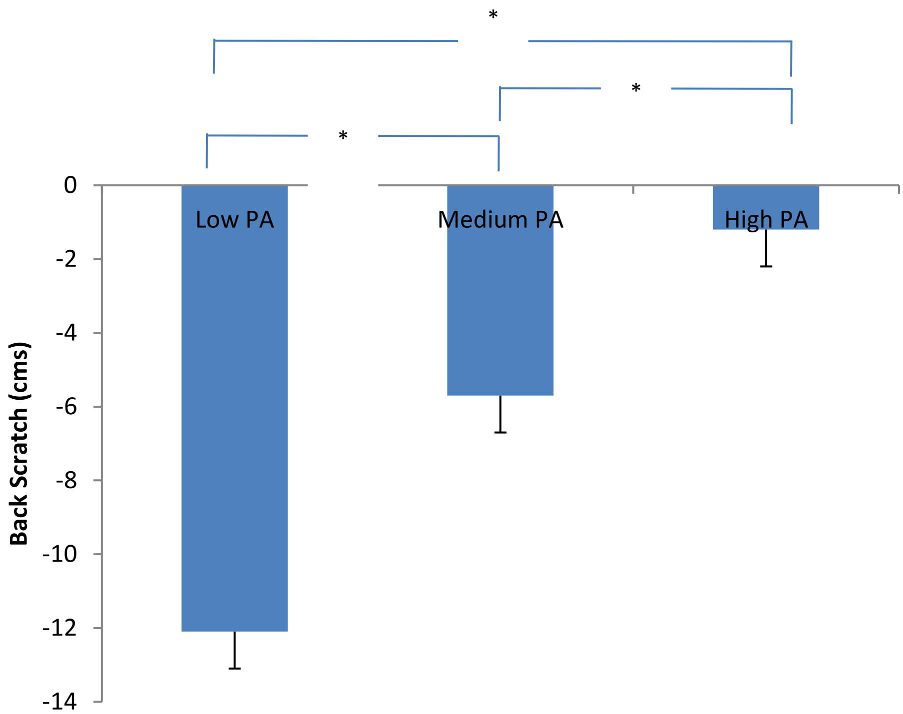
Six Minute Walk Test (Metres)
0
100
200
300
400
500
600
700
Low PA
Medium PA
High PA

e)



f)

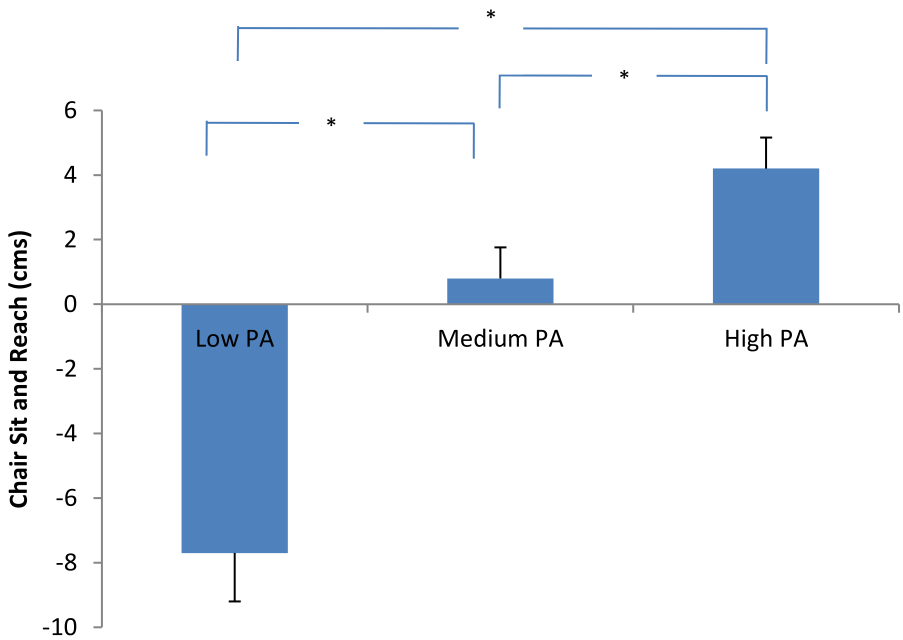


Figure 1. Mean ± SE of scores for a) chair stand, b) arm curl, c)8 foot timed up and go, d)six minute walk, e)back scratch and f)chair sit and reach tests in healthy adults aged 50-80 years (*P = 0.01).

Table 1. Mean ± SE of Body Mass Index (BMI), Waist Circumference (WC) and Body fat percentage between males and females and participants classified as low, medium or high habitual physical activity (PA). Coventry, UK, 2015.* P = 0.0001, ** P = 0.011, a P = 0.002 between low and medium PA, b P = 0.001 between low and high PA, c P = 0.001 between medium and high PA, d P = 0.009 between low and medium PA, e P = 0.002 between medium and high PA, f P = 0.002 between medium and high PA

	Gender		PA Dose		
	Male (n = 81)	Female (n = 120)	Low (n = 35)	Medium (n = 75)	High (n = 91)
BMI (kg/m^2)	28.6 (.53)*	26.6 (.35)	30.2 (.812)[a, b]	27.4 (.437)[c]	24.5 (.429)
WC (cm)	99.1 (1.1)*	86.6 (.93)	98.8 (1.78)[b, d]	92.8 (1.1)[e]	86.9 (1.1)
Body Fat (%)	30.3 (.76)**	32.8 (.63)	36.3 (1.22)[b, f]	31.6 (.78)[c]	26.7 (.750)

ANCOVA, controlling for age.

Table 2. Mean ± SE of functional fitness test values between males and females and participants classified as low, medium or high habitual physical activity (PA). Coventry, UK, 2015. * P = 0.015, ** P = 0.001, [a] P = 0.002 between low and high PA, [b] P = 0.001 between medium and high PA, [c] P =0.01 between low and medium PA, [d] P = 0.001 between low and high PA, [e] P = 0.001 between medium and high PA, [f, g] P = 0.001 between low and medium and low and high PA, [h] P = 0.001 between medium and high PA, [l] P = 0.004 between medium and high PA, [j] P = 0.015 between medium and high PA.

	Gender		PA Dose		
	Male (n = 81)	Female (n = 120)	Low (2501-5000 steps/day) (n = 35)	Medium (5001-7500 steps/day) (n = 75)	High (>7500 steps/day) (n = 91)
Chair Stand (no/30 secs)	14.7 (.51)**	14.9 (.43)	13.3 (.81)[a]	14.4 (.52)[b]	16.9 (.51)
Arm Curl (no/30 secs)	15.9 (.42)**	16.1 (.35)	13.7 (.61)[c, d]	15.8 (.43)[e]	18.4 (.41)
8 Foot Timed Up and Go (secs)	6.1 (.11)**	5.9 (.09)	7.3 (.17)[f, g]	5.8 (.11)[h]	5.1 (.11)
6 minute walk test (metres)	512.6 (8.4)**	503.2 (6.9)	445.2 (13.4)[f, g]	506.1 (8.5)[h]	572.6 (8.2)
Back Scratch (cms)	-7.7 (.94)*	-4.9 (.78)	-12.1 (1.5)[f, g]	-5.7 (.97)[i]	-1.2 (.93)
Chair Sit and Reach (cms)	-4.4 (.95)**	2.0 (.79)	-7.7 (1.5) [f, g]	0.8 (.96) [j]	4.2 (.96)

ANCOVA, controlling for age.