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Original Research

Parameters of Walking and Jogging in Healthy Young Adults

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ABSTRACT

Int J Exerc Sci 3(1): 4-13, 2010. The purposes of this study were to a) investigate the average heart rate (HR), speed, stride length, and stride rate during moderate intensity walking and jogging in healthy young adults, b) cross validate the walking stride length calculation based on 42% of height and c) provide reliability information for measurement of walking and jogging steps, speed, stride length, and stride rate. Participants (N=130) wore two Yamax SW-200 pedometers and a Polar A-1 HR monitor while performing walking and jogging trials. The correlation between estimated (0.71 ± 0.04 m·stride^{-1}) and actual stride length (0.78 ± 0.05 m·stride^{-1}) was moderate (r = .46). However, a significant difference was observed between the two measurements ($t(115) = -14.24$, $p < .001$). The reliability results for speed, stride length, and stride rate showed that two or fewer trials were enough to achieve reliable estimates. In conclusion, when instructed to walk at a moderate pace, healthy young adults tend to walk at an average pace that is greater than that recommended for meeting current public health recommendations (80 m·min^{-1}). Similarly, when instructed to jog at a comfortable pace, healthy young adults tend to jog at a speed greater than that corresponding to vigorous intensity physical activity (134 m·min^{-1}). The results of the reliability analysis indicate that in healthy young adults, to measure typical walking and jogging patterns using a pedometer, only two trials for walking and one trial for jogging are necessary to achieve reliable estimates. Stride rate calculations requires the combination of two trials and one pedometer for both walking and jogging.

KEY WORDS: Pedometer, reliability, step counts, heart rate, stride

INTRODUCTION

Regular physical activity (PA) can be effective in the primary and secondary care of several chronic diseases (e.g., cardiovascular disease, diabetes, cancer, hypertension, obesity, depression, and osteoporosis) and help prevent premature death (29). Because of the many benefits attributed to PA the American College of Sports Medicine and the American Heart Association have provided recommendations for the amount and intensity of PA needed to promote and maintain health, and lose weight (6, 11, 20). For healthy adults aged 18–65 yr it is recommended that they participate in moderate-intensity aerobic PA for a minimum of 30 min on at least five days each week or vigorous-intensity aerobic activity for a minimum of 20 min on at least three days each week (11). The most common activities associated with those recommendations are walking for moderate-intensity and jogging for vigorous-intensity.

Walking is also the most common type of PA in the United States with a prevalence of 33.6% (10). Researchers have investigated physiological (9, 24, 26) and biomechanical (18) aspects of walking across different samples in an attempt to describe patterns, determine if self-selected paces fulfill the recommended intensity for health benefits (19, 21), and how the term "brisk walking" is interpreted (19).

Running research has primarily focused on running economy, mostly focusing on trained runners (14). Leisure running has not been a focus of researchers. However, some studies have simultaneously looked at walking and jogging (9, 24) and focused on the PA aspect of running. In addition, there are a limited number of studies that provide basic information for self selected jogging/running speeds in untrained individuals (7).

The equipment necessary to accurately determine if PA is at a moderate or vigorous intensity level is expensive (e.g., accelerometers) and cumbersome (e.g., portable metabolic systems). The limitations of these tools make it difficult for members of the general public who are trying to improve their health to know if they are performing PA at the correct intensity level. However, cheaper and simple alternatives can be used to determine PA levels and describe activity patterns. One of those tools is the pedometer. Pedometers are simple devices whose primary function is to count steps (25). More advanced pedometers have a function to determine time spent in PA above a specified intensity (13). Even the simplest pedometers can be used to compute walking intensity. If the time spent walking or running is recorded, individuals can compute stride rate, which can then be compared to published recommendations (17, 28). Another device is the heart rate (HR) monitor. HR can be used to determine PA intensity because of the relatively linear relationship between HR and VO_2, and classification tables are available (2). HR was used recently in a study to investigate whether sedentary women could be trained to replicate moderate intensity walking (22).

The purposes of this study were to a) investigate the average HR, speed, stride length, and stride rate during moderate intensity overground walking and jogging in healthy young adults, b) cross validate the walking stride length calculation based on 42% of height as suggested by Hatano (12) and Bassett (4) and c) provide reliability information for measurement of walking and jogging steps, speed, stride length, and stride rate.

METHOD

Participants

Participants were exercise and sport science majors enrolled in a PA and fitness class at a university in the southeastern United States (*N* = 130). Data were collected as part of a series of controlled laboratories including measurement of body composition, PA, and fitness. Health, safety, and ethical principles such as voluntary participation are followed in all laboratories associated with the class. The university Institutional Review Board approved all procedures used in the study and provided approval for the secondary analysis of these data in order to answer the stated research questions regarding walking and jogging in young, healthy adults.

Instruments

Yamax SW-200. The Yamax Digiwalker (Yamax Corporation, Tokyo, Japan) pedometer is a simple pedometer with step count as its only function. This is one of the most used pedometers in research studies and interventions due to its high accuracy and low price (3, 25). The Yamax counts steps when vertical movement greater than 0.35 *g* is detected by the horizontal, spring-suspended lever arm.

Polar A-1. The Polar A-1 HR monitor (Polar Electro Oy, Kempele, Finland) was used to record HR and time. The HR monitor has the capability of tracking HR and exercise time, and storing average HR.

Procedures

Data collection. Testing was done in one session. Prior to participation, height was recorded to the nearest 1 cm using a Health-O-Meter stadiometer (Sunbeam Products, Inc., USA). At the beginning of the testing session, students were given verbal and written instructions and a data recording sheet. This lasted at least 5 minutes, at the end of which the students started the HR monitor and recorded resting HR. Participants were then split into pairs. Person 1 completed all walking and jogging trials first while Person 2 recorded the data, then they switched roles. Participants performed two walking trials followed by two jogging trials around an improvised oval indoor track within a basketball arena. The total distance of the track was 230 meters, but the start and finish points were about 20 meters apart, so finishers did not run into starters. Participants covered an exact distance of 211 meters, which was measured 3 times with a measuring wheel and the values were averaged.

Participants wore two pedometers on the right hip, above the knee/midline of the thigh, and a HR monitor. Instructions for the walk trials were to walk around at a moderate intensity and for the jogging trials participants were instructed to jog "at a comfortable pace". These instructions were deliberately kept simple in order to replicate the types of instructions typically provided to participants in community walking and jogging programs. Participants were instructed to walk around the inside of the track, staying close to the wall. They were also instructed not to walk together, and to leave sufficient time from the previous person before starting. At the start of each trial participants reset the pedometers and started the stop watch on the HR monitor. At the end of each trial, participants stopped the HR monitor stop watch and read out the pedometer steps. Step counts, average HR, and time were recorded. Between trials, participants waited for HR to drop below 100 beats$\cdot$min^{-1} before starting the next trial. If HR did not achieve 100 beats$\cdot$min^{-1} the next trial could be started without rest. A trained researcher was present for all data collection, standing next to the finish line supervising data collection and recording.

Data Management. The recorded data were inputted to Microsoft Excel. Estimated walking stride length was computed using the equation height$\cdot$42%, as suggested by

Hatano (12) and Bassett (4). Actual walking stride length was computed by dividing distance walked (211 meters) by the average step count from two pedometers across the two trials. Speed was computed in m/sec by dividing the distance walked (211 m) by the time (in sec). The speed in m/sec was then converted to m/min. Stride rate was computed by dividing the average step count (from two pedometers) by the time in min.

Data Analysis

Prior to data analysis, data were screened for equipment malfunction and outliers. An average of 15 data points were deleted from each measured variable. Data points were deleted when a systematic difference or variation above normal ranges were observed for the measure. Data analysis was performed using SPSS (version 15.0). Descriptive statistics were computed for all variables and data. Data were analyzed separately for the walking and jogging trials. For validation of the walking stride length equation, Pearson's correlation coefficient was computed to determine the relationship between the estimated and the actual stride lengths. A paired t-test was also used to compare mean estimated and mean actual stride length. The alpha level was set at .05. Generalizability theory, an extension of intraclass reliability (23), was used to determine reliability. The facets included were participants, trials, and number of pedometers. Generalizability theory is divided into two parts. The G-study can quantify the percent of variance associated with each variable and its interactions. G-study was used to determine the source of variance for step counts during walking and jogging trials. The second part of the generalizability theory, D-study, provides a Generalizability coefficient (G), making it possible to determine the measurement model needed to achieve a reliable estimate ($G \geq .80$). D-study was used to determine reliability coefficients for walking and jogging step counts, speed, stride length, and stride rate. GENOVA software (5) was used for the generalizability theory calculations.

RESULTS

Participants' average resting HR was 75 ± 10 beats $\cdot$min^{-1} and average height was 1.70 ± 0.10 m. The results from the walking trials can be found on table 1. The results from the jogging trials can be found on table 2. The correlation between estimated (0.71 ± 0.04 m$\cdot$stride^{-1}) and actual stride length (0.78 ± 0.05 m$\cdot$stride^{-1}) was moderate (r = .46). However, a significant difference was observed between the two measurements ($t(115) = -14.24$, $p < .001$, Cohen's D = 1.4). In this study stride rate corresponded to 46% of height. Participants accounted for the largest percentage of variance during both walking and jogging trials. For walking, participants accounted for 75% of the variance, the interaction between participants and trials accounted for 11%, and the participants x number of pedometers interaction accounted for 6%. The rest of the variance was unexplained. For jogging, participants accounted for 91% of the variance, the interaction between participants and trials accounted for 6%, trials accounted for 1%, and other variables and interaction accounted for less than 1% each.

For the reliability results, every variable measured needed two trials or fewer to achieve the desirable results ($G \geq .80$). For step counts, stride length, and stride rate,

Table 1. Walking trial results (*n* = 115).

Measure	Walk 1 Mean	Walk 1 SD	Walk 2 Mean	Walk 2 SD	Average Mean	Average SD
Heart Rate (beats·min^{-1})	106	15	107	15	107	15
Steps	275	19	271	19	273	18
Time (sec)	145.0	19.2	141.4	17.7	143.2	17.3
Speed (m·min^{-1})	88.6	10.9	90.9	11.2	89.7	10.3
Stride Length (m·stride^{-1})	0.77	0.05	0.78	0.05	0.78	0.05
Stride Rate (strides·min^{-1})	114	13	116	13	115	12

Note. SD = standard deviation

Table 2. Jogging trial results (*n* = 115).

Measure	Jog 1 Mean	Jog 1 SD	Jog 2 Mean	Jog 2 SD	Average Mean	Average SD
Heart Rate (beats·min^{-1})	152	18	159	16	155	16
Steps	186	31	181	30	183	30
Time (sec)	72.8	11.9	69.9	12.4	71.4	11.6
Speed (m·min^{-1})	179.9	28.2	187.6	35.9	183.7	30.5
Stride Length (m·stride^{-1})	1.17	0.20	1.21	0.22	1.19	0.21
Stride Rate (strides·min^{-1})	156	15	158	17	157	15

Note. SD = standard deviation

Table 3. G-coefficient for walk and jog trials.

Number of Trials	Number of Pedometer	Walk Steps	Walk Stride Length	Walk Stride Rate	Jog Steps	Jog Stride Length	Jog Stride Rate
1	1	.76	.75	.75	.92	.90	.77
1	2	.81	.80	.78	.96	.91	.78
2	1	.83	.83	.85	.93	.94	.86
2	2	.88	.88	.87	.96	.95	.87

the number of trials and the number of pedometers used during each trial were taken into consideration (see table 3). To achieve the desirable reliability, stride rate was the only measurement that required two trials, both for walking and for jogging. For step counts and stride length during walking, a combination of one trial and two pedometers was sufficient to achieve the desirable reliability. During jogging one trial and one pedometer was enough. For speed during walking two trials were necessary (G = .75 and .86 for one and two trials, respectively), and during jogging two trials were also necessary (G = .79 and .88 for one and two trials, respectively).

DISCUSSION

The main purposes of this study were to investigate the average HR, speed, stride length, and stride rate during walking and jogging, to cross validate a height-based walking stride length calculation, and to assess facets of reliability during walking and jogging, in healthy young adults.

During walking ,the HR response was similar to the response found in middle-aged adults by Schiffer et al. at a similar speed (24). The average stride length of 0.78 ± 0.05 $m\cdot stride^{-1}$ was similar to the stride length of 0.78 ± 0.04 $m\cdot stride^{-1}$ found in adults 18-65 years of age by Bassett et al. (3) when participants walked at a speed of 94 $m\cdot min^{-1}$. The average walking speed of 89.7 ± 10.3 $m\cdot min^{-1}$ was slower than the average observed walking speed of recreational walkers aged between 21 and 74 years (96.0 ± 14.4 $m\cdot min^{-1}$), and brisk walking speed (111.6 ± 7.2 $m\cdot min^{-1}$), measured by Murtagh et al. (19). However, the average walking speed was higher than the recommended speed of 80 $m\cdot min^{-1}$, equivalent to 3.3 METs (1) and considered moderate intensity (11). Additionally, the average stride rate of 115 ± 12 $strides\cdot min^{-1}$ was higher than the cut-points corresponding to minimal moderate intensity walking of 96 $strides\cdot min^{-1}$ in men and 107 $strides\cdot min^{-1}$ in women, or roughly 100 $strides\cdot min^{-1}$ for both established by Tudor-Locke et al. (28), and subsequently recommended by Marshall et al. (17). Overall the variables measured during walking demonstrated that the participants chose to walk at an intensity that was above the criteria typically used to classify moderate intensity. This finding is promising for health professionals wishing to encourage health-promoting physical activity, as it appears that simple instructions to walk at a moderate pace result in walking speeds and stride rates above those recommended in the public health literature. However, this may apply only to young, healthy adults such as those in the present study. Further research is needed into the walking speeds and stride rates of less fit, or older participants. For example, Jones et al. (15) demonstrated that older females select a slower walking pace than younger women, even though both groups were regular exercisers. Similarly, Fitzsimons et al. (8) demonstrated that women over 75 years walked at self-selected speeds approximately 20% slower than young women. Parise et al. (21) also found that older experienced walkers walked more slowly (80.5 $m\cdot min^{-1}$) than the current sample when asked to walk at their normal brisk pace.

During the jog the average HR in this study was lower than the HR measured by Schiffer et al. at a slightly slower speed (24). It was similar to the HR of young adults 25.8 ± 7.9 years of age in the first 3-6 min measured by Kilpatrick et al. (16), but the participants in his study were jogging at an average speed 50 m·min^{-1} slower than in the current study. Average jogging speed was well above the minimum speed (134 m·min^{-1}) identified as vigorous intensity, classified as greater than 6 METs (1, 11). The average speed of participants in this study fell between the speeds of 150 and 210 m·min^{-1} of a sample of college students tested by Elliott and Blanksby (7). The stride length and stride rates also fell between the values of 0.93 and 1.30 m·stride^{-1}, 155 and 173 strides·min^{-1}, respectively.

The correlation between the estimated walking stride length based on 42% x height (4, 12) and the actual stride length was moderate; however the means were significantly and meaningfully different, as indicated by Cohen's *D*. This finding does not support the use of 42% of height to estimate stride length (4, 12). The use of height to predict stride length should be done with caution.

For the percentage variance from the different variables it was demonstrated that participants played the major role, which is the desirable result for reliability purposes; the larger the percentage of variance explained by the participants facet, the higher the reliability will be. In both the walking and jogging trials the participants facet by itself or its interactions explained most of the variance. After the results from the G-study it was expected that the reliability coefficients would be high and for both walking and jogging trials only two or fewer trials were necessary to obtain reliable measurements of step counts, speed, stride length, and stride rate. This shows that in this population those measurements are stable. The finding of consistency between trials is relevant to laboratory studies of walking, and to applied PA promotion settings where typical walking speed or stride rate are to be investigated. Recently, there has been increased attention to stride rate and walking speed as an indicator of walking intensity under different conditions (8, 17, 19, 21, 27, 28). The current study reinforces the intertrial consistency of speed and stride rate over controlled walking and jogging trials, and the interinstrument consistency of simple lever-arm pedometers for such research. The participants tended to be slightly faster on the second trial, which influenced the average HR, steps, stride rate, and stride length. However, this was a trivial effect and did not appear to influence the reliability of the measurement during both the walking and jogging trial.

Limitations of the current study include the homogeneity of the sample (young, healthy adults), which may limit the generalizability to the general population. The lack of demographic data makes it impossible to precisely describe the sample. All data collection was supervised by a researcher, and the students had been trained during previous labs in data collection quality control. However, the trustworthiness of the student data collectors was not systematically evaluated in this study other than by spot checks conducted by the second author during data collection. This may have at least partly explained the need to completely delete 12 participants' data and partially delete eight participants' data with outlying or missing data. The average HR for the trials was recorded, but due to the short duration of the trials steady state might not have been achieved. This would lead to an under estimation of HR and consequently intensity of the activity. Strengths of the current study over many prior investigations of walking and jogging parameters are the inclusion of overground walking (which is more generalizable to real-world settings), a large sample size, and the use of a longer distance than prior research into overground walking (19, 27). Future research should investigate the influence of age, gender, and fitness level on the variables studied.

Overall, the results from this study are comparable to results found by previous researchers and provide a greater insight into walking and jogging, using readily available tools. Practitioners wishing to monitor their clients' PA, or individuals who would like to quantitatively measure their PA can benefit from the use of simple devices like a pedometer, to not only quantify the total amount of work performed (e.g., steps) but also the intensity of the work performed (e.g., steps$\cdot$min^{-1}).

In summary, when instructed to walk at a moderate pace, healthy young adults tend to walk at an average pace that is greater than that recommended for meeting current public health recommendations. Similarly, when instructed to jog at a comfortable pace, healthy young adults tend to jog at a speed greater than that corresponding to vigorous intensity PA. The results of the reliability analysis indicate that in healthy young adults, researchers investigating walking and jogging, and PA professionals wishing to reliably measure typical walking and jogging patterns can use a pedometer to measure steps (and subsequently stride length), and need only two trial with one pedometer (or one trial with two pedometers) for walking trials, or a single trial for jogging. Stride rate calculations require the combination of two trials and one pedometer for both walking and jogging.

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