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*Original Research*

# Physiological and Psychological Differences Between 20% Grade Incline Walking and Level-Grade Jogging at Isocaloric Intensity

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ABSTRACT

***International Journal of Exercise Science 17(6): 1318-1336, 2024.*** High-incline walking is a relatively new trend with little comparative information. This study compared physiological and psychological differences between high-incline walking at 20% grade (HIW) and level-grade jogging (LGJ) at isocaloric intensities in young adults. Twenty-two participants (M = 11, F = 11) aged 19–31 years completed the study. Participants completed HIW and LGJ on a treadmill for twenty minutes on two separate occasions and matched at isocaloric intensities. Rating of perceived exertion (RPE), maintainability (HCM), and affective valence using the Feeling Scale (FS) were measured at minutes 2, 10, and 20. Gas exchange and heart rate (HR) were continuously recorded. Post-exercise, participants completed the Physical Activity Enjoyment Scale (PACES) and 0–100 Likelihood scale. Relative oxygen uptake between LGJ and HIW (24.25 ± 3.53; 24.11 ± 3.63 mL/kg/min; $p = .570$, $d = -.12$), total calories (LGJ = 169.78 ± 35.80; HIW = 171.07 ± 35.09 kcal; $p = .504$), RER (LGJ = .86 ± .03; HIW = .88 ± .04; $p = .137$), and HR (LGJ = 146.28 ± 18.29; HIW = 143.94 ± 21.26 bpm; $p = .146$) was not different. LGJ (96.82 ± 15.76) had significantly higher total PACES (96.82 ± 15.76) and Likelihood scores (75.86 ± 18.30) than HIW (85.14 ± 15.08, $p < .001$; 65.09 ± 25.45, $p = .032$) respectively. RPE for both LGJ and HIW increased significantly with time ($p < .001$), but not between tests ($p = .312$). FS for LGJ and HIW increased significantly between tests ($p = .008$), but not between time ($p = .083$). At isocaloric intensities, young adults preferred and enjoyed LGJ relative to HIW.

KEY WORDS: Graded, oxygen consumption, perceptual

## INTRODUCTION

American adults are exhibiting more sedentary behaviors than previously estimated (41). These behaviors are not limited to older adults. Longitudinal studies have indicated that from adolescence to young adulthood, there's a general decline in physical activity (PA) (6). The recommended aerobic PA guidelines by the CDC and World Health Organization for adults 18–64 years of age is a minimum of 150 minutes of moderate-intensity aerobic physical activity per week or 75 minutes of vigorous-intensity aerobic PA per week, or an equivalent combination of both (50). Therefore, it is of great interest to continue exploring the barriers of exercise in young adults to increase the prevalence of PA.

A major barrier to starting and adhering to PA can be associated with a lack of intrinsic motivation or the inherent inclination to engage in an activity of interest and enjoyment (8,40,54). Having a more positive affective response or how an individual feels in response to exercise behavior has been associated with increased motivation and assists in sustaining the long-term motivation of exercise (59,61). In addition to affective response, multiple studies showed enjoyment as a strong predictor of higher levels of PA and long-term adherence to PA (25,35). Based on the literature, if PA is more enjoyable and pleasurable, a more consistent exercise routine may be achieved. Thus, exploring exercise modalities that elicit positive enjoyment and pleasure responses are worth investigating.

Walking and jogging are both common modalities of exercise (62). According to the 2018 International Health, Racquet and Sportsclub Association (IHRSA) Health Club Consumer Report, treadmills were the most popular piece of exercise equipment, with 43% of gym members using treadmills regularly (53). In line with the popularity of using treadmills, there has also been a recent trend in incline walking, leading to a rise in the production of high-incline treadmills. Further investigating this recent trend of exercise using high-incline grades is of interest.

Physiological, perceptual, and biomechanical parameters of level to moderate incline grades have been well investigated (38,39,48). From a biomechanical standpoint, studies have demonstrated that changes in gait patterns and muscle activation patterns do occur with moderate incline changes (14,42). However, the most prominent shifts occur at higher incline grades, specifically ~20% grade (16,43). Therefore, it is possible that level to moderate-grade work may not produce the same physiological and psychological responses of high-incline work at 20% grade.

From a psychological perspective, high-incline work is not well investigated. One study by Lankford et. al., (31) utilized incline walking to assess cardiorespiratory health ($VO_2$ max). After the participants completed traditional lower incline $VO_2$ max tests and the novel, high-incline (above 20%) tests, they were asked which they would prefer to perform. Half of the participants preferred a high-incline walking protocol compared to the traditional lower incline protocols (31). Conversely, Spackman et al., (58) found that 93.8% of all participants preferred a maximal graded test protocol with a lower average maximal incline grade (9.78% compared to 16.94%) in a similar population, indicating conflicting results. However, commonly used psychological parameters to measure enjoyment and affective valence, such as the PACES (27) and Feeling Scale (52) were not utilized in any of these studies. Additionally, participant preference was based on a maximal exertion assessment rather than the mode during sustained exercise. Therefore, the psychological parameters of high-incline work compared to lower-grade work at submaximal intensities are relatively unknown.

Previous research has been inconsistent with producing isocaloric intensities for comparing different modes of exercise. While using RPE as a primary measure to match intensities may equate to isocaloric intensities between two different modes of exercise (3), it has also been shown to result in non-isocaloric values (28). Early work by Dill suggests a linear increase in oxygen uptake as grade increased during walking (9), a primary component of the American College of Sports Medicine (ACSM) metabolic walking equation (60). This data suggests a similar biomechanical and metabolic efficiency as grade increases from level to moderate. Swain et al., (2016) utilized the ACSM metabolic equations to match the aerobic intensity of moderate incline walking (11%) to level-grade jogging, however the accuracy of the ACSM metabolic equation at high-incline grades (~20%) remains in question (32,36) due to possible biomechanical differences between low incline and high incline above ~18% grade. Research has shown that there is a distinct change in body mechanics at grades above ~18% (16,17,43), thus using a linear metabolic equation may not be as accurate when looking at higher-incline grades. To our knowledge, no studies have compared 20% grade incline walking to level-grade jogging, while maintaining both total calories and a sustainable relative work intensity and using relative $VO_2$ as the primary measure.

The purpose of this study was to compare physiological (indirect calorimetry, relative oxygen consumption, heart rate) and psychological (enjoyment, affective valence, rating of perceived exertion) differences between 20% grade incline walking (HIW) and level-grade jogging (LGJ) at isocaloric intensity in young adults. A secondary purpose of this study was to establish an isocaloric protocol to compare HIW with LGJ using relative $VO_2$ as the primary measure while maintaining constant duration and relative work intensity.

## METHODS

*Participants*

Participants were recruited through word of mouth and flyers. Participants were included in the study if deemed physically inactive and/or sedentary by getting less 150 minutes of moderate aerobic PA a week or 75 minutes of vigorous-intensity aerobic PA a week or an equivalent combination of both, consistently within the past six months according to Centers for Disease Control and Prevention (CDC) (50) and World Health Organization (WHO) (22) and within the ages of 19 to 31 years. Physical activity levels were determined through an exercise questionnaire which asks if participants answered yes or no to, “In the past 6 months, did you consistently get less than 150 min of moderate-intensity aerobic exercise or 75 min of vigorous aerobic exercise each week?” Participants with any major neurological, metabolic, cardiovascular, or orthopedic disorders, who required consent from a physician to exercise safely, or participating on any varsity athletic team were excluded from the study. This study was accepted by the university’s Institutional Review Board. All participants completed the Physical Activity Readiness Questionnaire (PARQ+) and written informed consent prior to participating in the study. This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science* (44).

*Protocol*
Three sessions were performed within two weeks, with at least 24 hours of rest in between sessions two and three. For the first session, participants formally consented, completed the PAR-Q+, exercise questionnaire, and anthropometric measurements. All participants underwent body composition analysis using air displacement plethysmography (BodPod®, Concord, CA), and is the gold standard for body density assessment (56), as well as test-retest reliability (47). Participants were reminded of the protocol for session two.

In session two, participants were asked to jog on level-grade. All participants were asked to eat within six hours, but not within two hours prior, refrain from caffeine, alcohol, and nicotine use at least four hours prior, and refrain from vigorous resistance training and aerobic exercise at least 14 hours prior to testing. Participants were weighed prior to exercise. Next, participants took a ~5 minute familiarization session to establish a jogging speed that was estimated below the lactate threshold on the Trackmaster TMX425C (Full Vision Inc., Newton KS) treadmill which represents a Respiratory Exchange Ratio (RER) of .83–.92, Borg's rating of perceived exertion (RPE) of 10–11, and were verbally affirmed to be comfortably sustained for at least 40 minutes. Breath by breath gas exchange analysis was analyzed using the ParvoMedics TrueOne 2400 (Parvo Medics, Sandy UT) metabolic cart. Heart rate was measured using a Polar H1 heart rate monitor (Polar, Kempele, Finland). Once speed was established, participants rested for ~5 minutes. Next, participants began level-grade jogging (LGJ) at the established speed and were asked to indicate their current Rate of Perceived Exertion (RPE), “How long can you maintain” scale (HCM), and the Feeling Scale (FS) at minutes 2, 10, and 20. The exercise bout lasted 20 minutes total. Immediately post exercise, participants were asked to complete the Physical Activity Enjoyment Scale (PACES) and the 0–100 likelihood scale. Participants were also reminded of the protocol for session three.

During session three, participants completed high incline walking. Session three took place a minimum of 24 hours after completing session two. All participants were asked to eat within six hours, but not within two hours prior, refrain from caffeine, alcohol, and nicotine use at least four hours prior, and refrain from vigorous resistance training and aerobic exercise at least 14 hours prior to testing. Participants were weighed prior to exercise and heart rate were measured using the Polar H1 heart rate monitor (Polar, Kempele, Finland). Next, the Lankford equation for oxygen uptake was used as a starting point for establishing an isocaloric speed (32). Participants then started a ~5 minute familiarization session and speed was adjusted to have the participants meet a respiratory exchange ratio (RER) of .83–.92, RPE of 10–11, was verbally affirmed that it could be sustained for 40 minutes, and match the Relative Oxygen Consumption ($VO_2$) (mL/kg/min) ± 3 from session two. Once speed was established, participants rested for ~5 minutes. Participants then began walking at the established speed and were asked to indicate their current Rate of Perceived Exertion (RPE), “How long can you maintain” scale (HCM), and the Feeling Scale (FS) at minutes 2, 10, and 20. The exercise bout lasted 20 minutes total. Immediately post exercise, participants were asked to complete the Physical Activity Enjoyment Scale (PACES) and 0–100 likelihood scale.

Prior to exercise, Rate of Perceived Exertion (RPE) (2) was explained to all participants. During LGJ and HIW, participants were asked to respond to the RPE (6–20), every two minutes. RPE is a 15-grade scale of whole-body perceived exertion, ranging from 6–20 (2). A rating of 6 indicates "no exertion at all" and a rating of 20 indicates "maximal exertion.""

All participants were asked to respond to the Feeling Scale for measure of affective behavior during LGJ and HIW at minutes 2, 10, and 20. The FS consists of a 11-point bipolar scale that ranges from +5 (very good) to −5 (very bad) (52) and represents an individual's feelings of pleasure or displeasure to exercise at that moment. Prior to HIW and LGJ bouts, according to Hardy & Rejeski, (24), the following was read to each participant: "While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. When asked during exercise, please respond how you truly feel at that moment."

All participants were asked to respond to the question: "How long can you maintain?" (HCM) during LGJ and HIW at minutes 2, 10, and 20 to ensure that the trials could be completed. The HCM consists of an 8-grade scale with 5-minute increments that ranges from 10 minutes to 50 minutes. The HCM was used as an indirect guidance for the participants' sustainability of LGJ and HIW.

After concluding LGJ and HIW, all participants were asked to fill out the Physical Activity Enjoyment Scale (PACES) (27). The PACES consists of a 7-point Likert scale with 18 items (11 negatively worded items and 7 positively worded items). The PACES can be scored between 18 and 126, with higher scores indicating a more positive feeling or enjoyment of exercise.

Fat and carbohydrate oxidation rates (g/min) were calculated using stoichiometric equations by Frayn (15) and protein oxidation was excluded. Nitrogen urinary excretion is assumed negligible. $VO_2$ and $VCO_2$ (L/min) values were measured during the 20-minute bout for LGJ and HIW.

$$\text{CHO (g/min)} = 4.55\times(VCO_2\ \text{L/min}) - 3.21\times(VO_2\ \text{L/min})$$
$$\text{FAT (g/min)} = 1.67\times (VO_2\ 2\ \text{L/min}) - 1.67\times(VCO_2\ \text{L/min})$$

*Statistical Analysis*

For the primary purpose, a paired *t*-test, two-tailed, was used to compare average fat oxidation (g), mean carbohydrate oxidation (g), mean respiratory exchange ratio, mean heart rate, mean PACES scores, and mean likelihood scores to determine any differences between LGJ and HIW. The Shapiro-Wilk test for the assumption of normality was used to assess if the data was normally distributed. A two-factor mixed model ANOVA was used to compare RPE, FS, and HCM at minutes 2, 10 and 20-minute averages between LGJ and HIW. Regardless of the interaction, a priori planned comparison was conducted for differences over time between perceptual measures of RPE, FS, and HCM using Bonferroni corrected post hoc tests. If the assumption for sphericity was violated, Greenhouse-Geisser corrected interpretations were used. Significance was set at $p < .05$.

For the secondary purpose, a paired *t*-test was also used to determine if $VO_2$ was isocaloric between LGJ and HIW. A linear regression (slope, y-intercept), Pearson's Correlation Coefficient, and Bland Altman plots were used to assess the isocaloric relationship between mean $VO_2$ of LGJ and HIW. For the slope of mean $VO_2$ of LGJ and HIW, the null hypothesis for the slope was that it was equal to one (increasing equally). For the slope of mean $VO_2$ of LGJ and HIW, the null hypothesis for the y-intercept was that it was equal to zero (started at the same point). Lastly, for Pearson's Correlation Coefficient, null hypothesis testing was that mean $VO_2$ for LGJ and HIW was equal to zero. Significance was set at $p < .05$.

## RESULTS

A total of 30 subjects agreed to participate in the study. However, five subjects were excluded from the final analyses for not adhering to pre-test guidelines, not completing the protocols within two weeks, or simply dropping out of the study. Three subjects were also excluded from the final analyses since the treadmill speed did not meet the threshold to elicit a visible jog during the LGJ session. Thus, the total subject pool included in the final analysis was $n = 22$ (11 males, 11 females) (See Table 1).

Descriptive data for mean LGJ and HIW speed (mph) are found in Table 2.

**Table 1.** Subject anthropometric and descriptive information.

| | Mean ± SD |
|---|---|
| Age (yr) | 24.32 ± 4.12 |
| Height (cm) | 168.63 ± 8.50 |
| Weight (kg) | 71.03 ± 12.73 |
| BF % | 25.19 ± 9.26 |

Values are represented by mean ± SD. $n = 22$. BF % = body fat percentage.

**Table 2.** Subject treadmill speeds.

| | Mean ± SD | |
|---|---|---|
| | LGJ | HIW |
| Speed (mph) | 3.94 ± .55 | 1.81 ± .31 |

Values are represented by mean ± SD. $n = 22$. LGJ = level-grade jogging; HIW = high-incline walking.

Data for the paired-samples *t*-tests are found in Table 3. The Shapiro-Wilk test for the assumption of normality showed no significant violation of normality ($p > .05$), indicating normal distribution of the data. Mean $VO_2$ consumption (mL/kg/min) was no different between LGJ (24.25 ± 3.53) and HIW (24.11 ± 3.63; $p = .570$, $d = -.12$). During LGJ (169.78 ± 35.80), total calories (kcal) utilized by subjects was no different than HIW (171.07 ± 35.09; $p = .504$, $d = .15$). Total fat oxidation (g) during LGJ (7.74 ± 2.50) was no different than during HIW (6.85 ± 2.51; $p = .073$, $d = -.40$). Total carbohydrate oxidation (g) during LGJ (25.01 ± 5.98) was no different than HIW (27.34 ± 7.82; $p$ = .101, $d$ = .37). Similarly, RER during LGJ (.86 ± .03) was no different than HIW (.88 ± .04; $p$ = .137, $d$ = .33). Total heart rate (bpm) during LGJ (146.28 ± 18.29) was no different than HIW (143.94 ± 21.26; $p$ = .146, $d$ = −.32). However, LGJ (96.82 ± 15.76) had significantly higher total PACES scores compared to HIW (85.14 ± 15.08; $p$ = < .001, $d$ = −.87). LGJ also had significantly higher likelihood scores (75.86 ± 18.30) than HIW (65.09 ± 25.45; $p$ = .032, $d$ = −.49).

**Table 3.** Paired-samples *t*-test comparisons between LGJ and HIW.

| | Mean ± SD | | | | | |
|---|---|---|---|---|---|---|
| | LGJ | HIW | *t* | *df* | Sig. | *d* |
| $VO_2$ (mL/kg/min) | 24.25 ± 3.53 | 24.11 ± 3.64 | −.56 | 21 | .570 | −.12 |
| Kilocalorie (kcal) | 171.07 ± 35.09 | 169.78 ± 35.80 | .68 | 21 | .504 | .15 |
| FAT (g) | 7.74 ± 2.50 | 6.85 ± 2.51 | −1.98 | 21 | .073 | −.40 |
| CHO (g) | 25.01 ± 5.98 | 27.34 ± 7.82 | 1.71 | 21 | .101 | .37 |
| RER | .86 ± .03 | .88 ± .04 | 1.55 | 21 | .137 | .33 |
| HR (bpm) | 146.28 ± 18.29 | 143.94 ± 21.26 | −1.51 | 21 | .146 | −.32 |
| PACES | 96.82 ± 15.76 | 85.14 ± 15.08 | −4.07 | 21 | < .001* | −.87 |
| Like | 75.86 ± 18.30 | 65.09 ± 25.45 | −2.30 | 21 | .032* | −.49 |

Values are represented by mean ± SD. * $p$ < .05, two-tailed. LGJ = level-grade jogging; HIW = high-incline walking; $VO_2$ = relative volume of oxygen consumption (mL/kg/min); Kcal = kilocalorie; FAT = total fat oxidation (g); CHO = total carbohydrate oxidation (g); RER = respiratory exchange ratio; HR = heart rate (bpm); PACES = Physical Activity Enjoyment Scale; Like = likelihood scale.

Using Greenhouse-Geisser's correction, there was a significant main effect across time on RPE between LGJ and HIW ($F$(1, 25) = 34.91, $p$ = < .001, $\eta^2$ = .31) (See Figure 1). Bonferroni's Post Hoc test indicated significant changes across time were observed during LGJ for RPE only between minutes two (10.09 ± 1.48) and ten (11.23 ± 1.48; $p$ = < .001, $d$ = .73). During HIW, there were also significant changes in RPE only between minutes two (10.32 ± 1.36) and ten (11.73 ± 1.42; $p$ < .001, $d$ = .90). However, there was no significant main effect of protocol on mean RPE scores between LGJ and HIW ($F$(1,21) = 1.07, $p$ = .312, $\eta^2$ = .02). There were also no significant changes in interaction of RPE across time and the protocol ($F$(2,42) = .41, $p$ = .666, $\eta^2$ = .002).

There was a significant main effect of protocol on mean FS scores between LGJ and HIW ($F$(1,21) = 8.55, $p$ = .008, $\eta^2$ = .103) (See Figure 2). Bonferroni's Post Hoc test indicated the mean scores of FS were significantly different only during minute 20 for LGJ (2.05 ± 1.70) and HIW (1.14 ± 1.52; $p$ = .006, $d$ = .62). There were no significant main effects of FS across time for both LGJ and HIW ($F$(2,42) = 2.64, $p$ = .083, $\eta^2$ = .054). There were also no significant interactions in FS between time and protocol ($F$(2,42) = 3.10, $p$ = .055, $\eta^2$ = .020).

Using Greenhouse-Geisser's correction, there was a significant main effect only across time for HCM between LGJ and HIW ($F$(1,25) = 22.68, $p$ = < .001, $\eta^2$ = .315) (See Figure 3). Bonferroni's Post Hoc test showed significant changes across time in HCM during LGJ minutes two (42.05 ± 8.26) and ten (36.36 ± 10.49; $p$ = .014, $d$ = .50). However, there was no significant main effect of protocol on mean HCM between LGJ and HIW ($F$(1,21) = 1.87, $p$ = .186, $\eta^2$ = .026). Using

Greenhouse-Geisser's correction, there was also no significant interaction with HCM between LGJ and HIW ($F(1,32) = .133$, $p = .825$, $\eta^2 = .00$).

Results for the Linear Regression are found in Table 4, Figure 4. The intercept, $\beta_0 = .525$ [−3.313, 4.363] was not significantly different from zero ($t = -.366$, $p = .778$). The slope, $\beta_1 = .972$ [.816, 1.129] of the linear relationship between the $VO_2$ consumption for the HIW and the LGJ treatments was not significantly different ($t = -.366$, $p = .778$). A test for the significance of the linear correlation between the mean $VO_2$ consumption for the HIW and LGJ treatments was statistically significant, with a strong positive correlation ($p < .001$, r = .945 [.870, .977]).

Bland-Altman analysis did not reveal any systematic differences between the $VO_2$ consumption for the HIW and LGJ treatment (See Table 5, Figure 5).

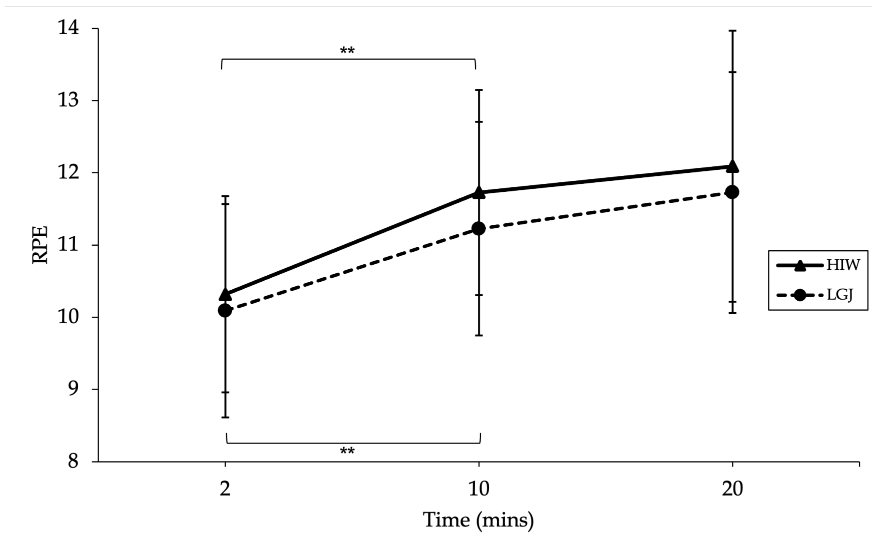


**Figure 1.** Line graph of the mean RPE for LGJ and HIW across time. ** = $p < .001$ indicates significant difference between minutes 2 and 10 for LGJ and HIW, two-tailed. Error bars represent standard deviation of the mean. HIW = high-incline walking; LGJ = level-grade jogging.

**Table 4.** Linear Regression and Pearson's Correlation Coefficient comparison between HIW and LGJ.

| | $\beta_0$ | $\beta_0$ | *r* | *t* | *df* | Sig. | 95% CI |
|---|---|---|---|---|---|---|---|
| Intercept | .525 | - | - | .285 | 20 | .778 | (−3.313, 4.363) |
| Slope | - | .972 | - | −.366 | 20 | .718 | (.816, 1.129) |
| Pearson's | - | - | .945 | 12.946 | 20 | < .001** | (.870, .977) |

** = $p < .001$, two-tailed. $\beta_0$ = y-intercept of the linear regression. $\beta_1$= slope of the linear regression. r = Pearson's Correlation Coefficient.

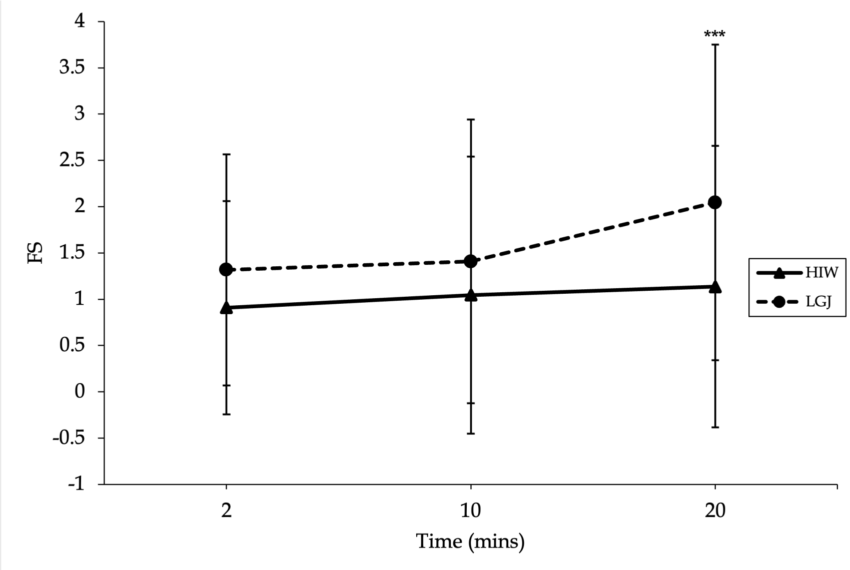


**Figure 2.** Line graph of the mean FS for LGJ and HIW across time. *** = $p < .01$ indicates significant difference between LGJ and HIW at minute 20, two-tailed. Error bars represent standard deviation of the mean. HIW = high-incline walking; LGJ = level-grade jogging.

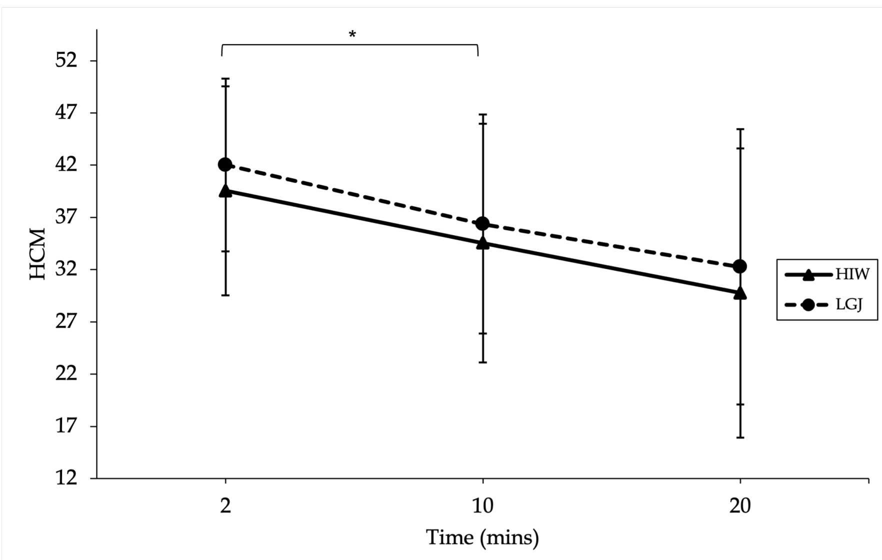


**Figure 3.** Line graph of the mean HCM for LGJ and HIW across time. * = $p < .05$ indicates significant difference between minutes 2 and 10 for LGJ, two-tailed. Error bars represent standard deviation of the mean. HIW = high-incline walking; LGJ = level-grade jogging.

**Table 5.** Bland Altman comparison between HIW and LGJ.

| | $\bar{d}$ | SD | $\bar{d} \pm 1.96 \times SD$ |
|---|---|---|---|
| $VO_2$ | −.143 | 1.19 | (−2.475, 2.190) |

$\bar{d}$ = mean of the differences in $VO_2$. SD = standard deviation of the mean. $VO_2$ = relative volume of oxygen consumption. HIW = high-incline walking; LGJ = level-grade jogging.

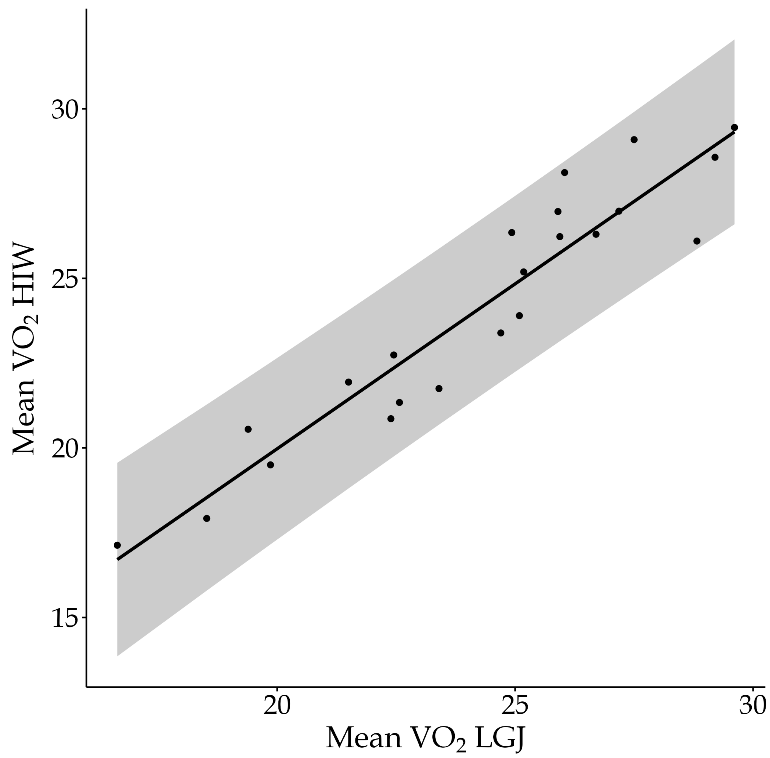


**Figure 4.** Scatter Plot of the mean $VO_2$ for the LGJ and HIW sessions with the linear regression prediction intervals. $VO_2$ = relative volume of oxygen; LGJ = level-grade jogging; HIW = high-incline walking.

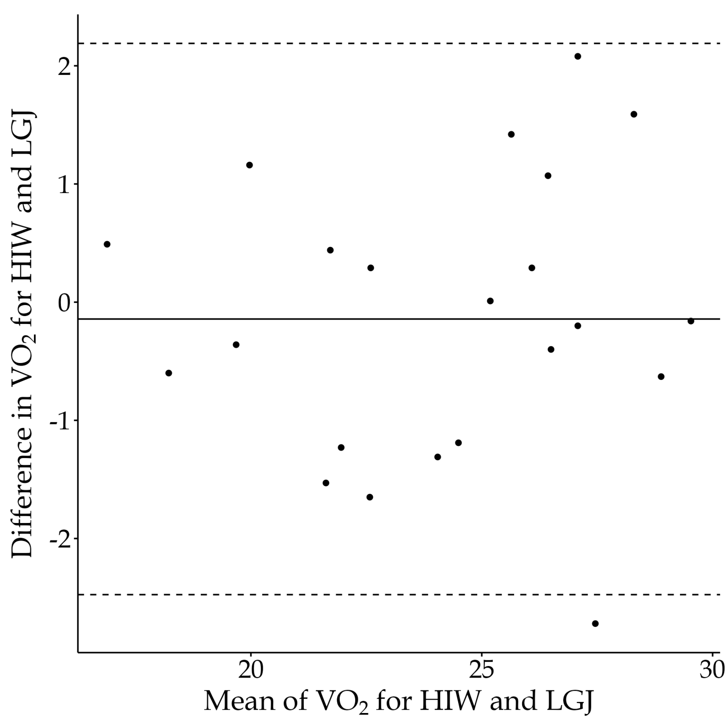


**Figure 5.** Bland-Altman plot comparing the difference and mean of the $VO_2$ for HIW and LGJ. HIW = high-incline walking; LGJ = level-grade jogging.

**DISCUSSION**

A possible explanation, at least in part for the higher total enjoyment and affective valence measures (during minute 20) observed during LGJ compared to HIW may be due to a change in gait during HIW, which caused changes in muscle activation patterns. Lankford et al., (32) demonstrated that incline walking above grades of 15% induced a leg swing pattern that mimics a walking lunge when compared to level-grade walking. Although gait was not measured in the current study, during HIW, participants walked at an incline-grade greater than 15%. Gidley & Bailey (16) also quantified differences in walking mechanics at high incline grades on the treadmill. More specifically, the walking mechanics at grades above 15% shifted coordination patterns in a way that prioritized lifting the body's center of mass (16). The coordination at higher inclines showed that the hip and knee were extending at the same time through a large range of motion, more like a lunge. Furthermore, when comparing incline walking with level-grade walking, studies have demonstrated greater lower extremity muscle activation patterns of the gluteus maximus, quadriceps, hamstring, the gastrocnemius and the soleus (14,30,34,57). In addition, other variables that contribute to changes in uphill muscle activation patterns include foot strike patterns (37) and an overall increase in power output of the joints (74). All of this evidence suggests that HIW is more like a lunge, where inverted pendular mechanics are lost, the major joints of the leg move through a greater range of motion and the muscles that cross the hip and the knee, in particular, have greater muscle activation. Therefore, walking with a gait more similar to a walking lunge may have led to the participants psychological responses being more similar to that of body-weight resistance exercise.

In the present study, intensity was matched only using relative $VO_2$. Physiological changes during higher intensity exercise of resistance or aerobic activity, such as increased muscle activation patterns may cause a disruption in homeostasis, leading to subsequent changes in affect and enjoyment response (4,20). Although the participants in the current study were estimated to be working below the lactate threshold at isocaloric intensities, changes in muscle activation patterns during HIW may have replicated the stimuli of resistance or bodyweight exercise, while LGJ did not. However, the participants were not truly above the lactate threshold, as indicated by the RER, RPE, and HR. This may help explain the participants' indicating significantly higher affective valence (minute 20) and levels of enjoyment during LGJ compared to HIW. In a study by Greene & Petruzzello, (20), affective valence and enjoyment levels were measured at various time points at resistance training intensities of 100% 10 repetition max and 70% 10 repetition max in college-aged adults. The participants reported increased affective valence levels via FS during the lower intensity resistance condition compared to a decrease during the higher intensity condition (20). Furthermore, enjoyment levels measured via PACES were significantly higher for the 70% intensity condition compared to the 100% intensity condition (20). Recently, a study by Hutchinson et al., (26) reported similar results in affect, indicating higher affective valence in the lower intensity resistance exercise condition compared to the higher intensity resistance exercise condition. Although the current study utilized an aerobic exercise protocol at isocaloric intensity, HIW in the current study appears consistent with the resistance exercise literature that an increase in muscle activation patterns does not always elicit more positive affective valence or enjoyment responses. It's important to note, the current study matched relative $VO_2$, which is a measure of the oxygen utilized by the skeletal muscle between LGJ and HIW (51). Thus, it can be assumed that total body skeletal muscle utilization of $VO_2$ was equivalent. However, muscle activation patterns likely differed, which resulted in a more unfavorable psychological response during HIW compared to LGJ. Therefore, future studies may want to compare the muscle activation patterns of high-incline walking and body-weight resistance exercise to indicate the degree of similarity between the two modes of exercise.

Using the framework of the Dual-Mode Theory (DMT), the positive affective valence reported by participants in the current study may be due to exercising in the first metabolic domain, or intensities below or up to the ventilatory threshold (11). Mean RPE scores for both HIW and LGJ ranged from 10–11 and mean RER was .86–.88, indicating that subjects were exercising below the lactate threshold (7,55,65). It's important to note slight deviations in mean HR compared to RPE values were observed. Mean HR values were higher than the reported RPE values, however, corresponding RPE values through conversions were still within range for moderate intensity exercise (54). Therefore, RPE, HR, and RER measured in subjects indicate that exercise was performed below the lactate threshold during HIW and LGJ.

Mean affective valence for LGJ was significantly higher than HIW during minute 20. However, affective valence scores during minutes 2, 10 and 20 were still positive for both sessions. According to DMT, exercising below or up to the lactate threshold mostly show positive affective valence in healthy individuals, although inter-individual variability plays a role as well (10,11). Our findings corroborated the DMT, with affective valence remaining positive in the subjects during both HIW and LGJ. Although non-significant, all of the mean FS values increased across time during the 20-minute HIW and LGJ sessions. A study by Hammer et al., (23) showed similar results in subjects participating in 45-minutes of continuous moderate-intensity jogging, indicating no decreases and overall positive affective valence during the exercise bout. Similarly, a study by Niven et al., (46) showed that although non-significant, the differences in positive affective valence increased over time in young, untrained males cycling at moderate intensity below the ventilatory threshold. Our findings, along with others, appear to support the DMT's framework that exercising below the lactate threshold evokes an overall positive affective valence response in young healthy individuals.

Enjoyment levels for LGJ were significantly higher than HIW, which may be useful for maximizing aerobic exercise adherence. Additionally, immediately post-test, the participants reported significantly higher likelihood levels of returning to LGJ for exercise in the future compared to HIW. Although the participants did not receive a follow-up after concluding the study, an indication of higher likelihood levels for LGJ appears consistent with the hypothesis that enjoyment is a critical component for long-term exercise adherence (12). Furthermore, an expanding body of literature suggests an intervention to PA or exercise prescription that prioritizes maximizing enjoyment is more likely to be effective for adherence and adoption (35,63). These findings are crucial to further understand the relationship between enjoyment and exercise, ultimately to facilitate greater physical activity engagement and adherence. This warrants the continued exploration of the effectiveness of long-term PA and exercise interventions that prioritizes enjoyment in physically inactive adults.

Evidence in the literature suggests that fewer individuals participate in muscle-strengthening exercise compared to aerobic exercise in the United States (1,12). In 2020, only 6% of adults in the United states met the recommended guideline for just muscle-strengthening, while 22.7% of adults met the aerobic exercise guidelines (12). The low prevalence in muscle-strengthening exercise may be supported by factors such as socioeconomic (12) and geographical (1) barriers, but enjoyment during exercise may also be a contributing factor. If the participants experienced less enjoyment during HIW because of changes in muscle activation patterns, similarly to resistance or bodyweight exercise, it may in part support the evidence of the low prevalence of individuals meeting the recommendation for muscle strengthening exercise compared to aerobic exercise.

Age may have been a contributing factor for LGJ being reported as more enjoyable than HIW. The sample population of the current study were physically inactive, but healthy young adults, free from injuries may have influenced the perception of higher enjoyment levels towards LGJ. Age-related changes in dynamic balance control or an assessment of one's ability to maintain balance through disturbances in equilibrium (45), follow an inverted U-shaped curve over one's lifespan (19). In other words, during one's youth, dynamic balance control increases, peaks in young adulthood, and declines as seniors (19). Age-related changes in dynamic postural control or the capability of an individual to sustain natural balance when exposed to disturbances in equilibrium (5), has also been shown in older adults compared to younger adults (13). Research has demonstrated that older adults have reduced mechanical efficiency and increased co-activation of lower limb muscles relative to younger populations (48). These changes may become exacerbated when comparing running to walking. As a result, changes in mechanical efficiency may contribute to the balance alterations observed in older adults causing older populations to feel more comfortable walking at an incline compared to level-grade jogging when relative intensity is matched. Additionally, chronic joint dysfunction such as Osteoarthritis affecting the knees and hips are prevalent amongst older adults and increases with age (33). Level-grade jogging has also been shown to induce higher vertical ground reaction forces on the lower extremity compared to graded exercise, which could exacerbate the symptoms of Osteoarthritis (18,59). Due to additional age-related factors such as increased tendon stiffness (29) and musculoskeletal stiffness (64), 20% grade incline walking may be more comfortable for older populations during HIW compared to LGJ. In the current study on young adults, it can be speculated that the changes in muscle activation patterns during HIW, paired with the lack of age-related impairments during LGJ, may explain the participants' enjoyment of LGJ over HIW. However, in older adults, decreases in postural stability and other age-related physiological declines, coupled with higher impact forces during LGJ may be unfavorable, which could influence the outcome of enjoyment between LGJ and HIW. Therefore, it may be meaningful for future studies to replicate the current study with a sample population consisting of older adults.

Isocaloric intensities were successfully achieved through statistical analyses. First, using a paired-samples *t*-test, non-significant differences in subject mean $VO_2$ and kilocalorie were identified between HIW and LGJ. A Bland-Altman analysis was also utilized and did not identify any systematic differences between $VO_2$ consumption for HIW and LGJ. There were no clear trends in the relationship found between the difference in $VO_2$ means between LGJ and HIW. A linear regression determined that the slope between $VO_2$ consumption was not significantly different from each other for LGJ and HIW. Furthermore, the y-intercept was not significantly different from zero, indicating that the slope of the $VO_2$ between LGJ and HIW nearly began at the same point. Lastly, Pearson's correlation coefficient between mean $VO_2$ consumption of LGJ and HIW reported a strong positive relationship, indicating a high degree of association between the two conditions. To the best of our knowledge, this is the first study that controlled both caloric expenditure, intensity, and time to reach isocaloric requirements between two modes of exercise; 20% grade incline walking and level-grade jogging.

Total kilocalories are used as a criterion to determine isocaloric intensities. Once a subject reaches a specific threshold of total calories or absolute $VO_2$ expended during a protocol, the test is terminated. The same total calories are then matched to a different protocol and the test is terminated once the threshold is reached, irrespective of duration (21,49). However, when matching intensities between two different modes of exercise, a study by Brown et al., (3) utilized a methodology more similar to the present. The researchers used a five-minute warm-up stage on a 0% grade treadmill and elliptical to establish a RPE of 12–13 based on the subject's perception. The untrained college-aged subjects continued at the self-selected intensity for 15 minutes on the treadmill and elliptical. It's important to note that the speed of the treadmill or the resistance of the elliptical were continuously modified by the subjects during the sessions. The results indicated that RPE, total oxygen consumption (L) and total energy expenditure were statistically non-significant between the treadmill and elliptical. However, mean heart rate and mean RER were statistically higher on the elliptical than on the treadmill. It's critical to note a few differences in the present study compared to the one by Brown et al., (3). The first being that the mode of exercise differed and mean RPE was lower (10–11). Second, although subject RPE was used as a gauge during the pretest for LGJ and HIW, the main measure in the present study was to match the subject's relative $VO_2$. Third, the participants modified speed or resistance throughout the duration of each protocol to sustain the target RPE values. However, in the current study, speed was not modified by the participants, and instead set at an established, continuous speed for the entirety of the 20-minute LGJ and HIW protocols. Similarly, no differences were found between $VO_2$ consumption between HIW and LGJ, however, unlike the findings by Brown et al., (3), RER and mean heart rate were also not significantly different. The methodology of the present study supports the notion that matching relative $VO_2$ at intensities below the lactate threshold during LGJ and HIW on a treadmill, results in isocaloric intensity.

Others have utilized RPE as a main measure to match intensities between two modes of exercises as well (28). The researchers matched a RPE of moderate intensity between graded walking and ungraded jogging in untrained adults. The methodology matched a target RPE of 13 as the main measure, irrespective of $VO_2$ and total energy expenditure. Speed was modified during the running trial and grade was manipulated during the incline walking trial to match the subject's target RPE of 13 throughout the 30-minute duration. Although RPE was the same for both trials, there were significant differences in heart rate, $VO_2$ (mL/kg/min), and total caloric expenditure (kcal). One aspect in the present study that differed from Kilpatrick et al., (28) is that speed or grade was not manipulated to match a target value and remained consistent. Additionally, the mean of the graded walking session was only 10.2%, while the present study utilized a 20% gradient (28).

The definition of “matching intensities" appears to be ambiguous and the methodology used is dependent on the primary outcome of a study. The present study is unique in that all physiological measures ($VO_2$, total Kcal, RER, HR), alongside perceptual measures such as RPE were statistically non-significant between two different modes of exercise, resulting in isocaloric intensity. Perhaps using relative $VO_2$ as a main measure for matching intensities between different modes of exercise may result in more equivalent physiological values than subjective measures such as rating of perceived exertion. As there is not a precedence on matching intensity of exercise between various graded incline walking and level-grade jogging, the current methodology of matching relative $VO_2$ may be replicated in future studies to establish further validity and reliability. It should be noted that a limitation was that the participants were required to sustain a jogging speed in-order to match it with HIW. In the current study, three participants met all criteria, except sustaining a jogging speed. Therefore, future studies should take this into consideration when attempting to match different modes of exercise.

It’s worth noting the mean treadmill speed of LGJ was 3.94 mph and HIW was 1.81 mph with equivalent physiological values during the 20-minute duration. Using these metrics together with the help of smart health devices, it may be useful for individuals engaging in exercise protocols that would like to target specific caloric and metabolic values. For example, individuals have the autonomy to choose between 20-minute level-grade jogging or 20% grade incline walking on a treadmill, knowing that similar caloric and metabolic values could be achieved.

The purpose of this study was to compare physiological (indirect calorimetry, relative oxygen consumption, heart rate) and psychological (enjoyment, affective valence, rating of perceived exertion) differences between 20% grade incline walking and level-grade jogging at isocaloric intensity. We found that in young, physically inactive adults, level-grade jogging produced higher affective valence (minute 20) and likelihood scores, and was perceived as more enjoyable compared to 20% grade incline walking at isocaloric intensities, which may be useful in the context of adoption and adherence to physical activity. There were no significant differences found in physiological measures ($VO_2$, total Kcal, RER, fat (g), carbohydrate (g), HR). The psychological differences we found may be attributed to changes in muscle activation patterns during high-incline walking. However, future research could investigate age-related factors that may contribute to the psychological preferences of 20% grade incline walking and level-grade jogging in older populations.

A secondary purpose of this study was to establish an isocaloric protocol to compare incline walking with level-grade jogging, where duration and intensity were constant. Based on statistical analyses, the protocol for matching intensity with relative $VO_2$ between level-grade jogging and 20% grade incline walking resulted in isocaloric $VO_2$ values. Our findings provide insight on the approximate treadmill speed that induces matching caloric expenditure during 20% grade incline walking and level-grade jogging.

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