Research Article

Acute effect of uphill and downhill treadmill walk on cardiovascular response and perceived exertion in young sedentary individual

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ABSTRACT

Background: Systematic exercise is an essential component for health promotion and improvement of the quality of life. Exercise that emphasizes on the eccentric (lengthening) skeletal muscle contractions has recently gained attention due to its benefits over conventional exercise that predominantly involves concentric (shortening) muscle contractions. The mechanical efficiency of walking on an inclined (uphill) and a declined (downhill) treadmill is equivalent to those of concentric and eccentric muscle contraction, respectively. **Objective:** To compare the acute effect of uphill (concentric exercise) and downhill (eccentric exercise) treadmill walk on physical exertion and cardiovascular response. **Materials and Methods:** The present crossover study involved 30 males, aged 20.6 ± 1.9 years, having a body mass index of 20.7 ± 1.4 kg/m^2. Participants did an acute bout of uphill (+0.16 grade) and downhill (−0.16 grade) treadmill walk at an average speed of 4.6 ± 0.4 km/h for 30 min. Borg's 6-20 scale rating of perceived exertion (RPE), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), mean arterial pressure (MAP), pulse pressure (PP), and rate pressure product (RPP) were the study parameters. Statistical analysis was done using paired *t*-test or Wilcoxon test. **Results:** The downhill walk caused a significant ($P < 0.05$) lower mean change in SBP, HR, MAP, PP, RPP, and RPE (26.7 ± 5.6, 58.2 ± 6.8, 16.2 ± 6.1, 15.9 ± 4.1, 106.3 ± 14.5, 12.5, respectively) as compared to uphill walk (22.3 ± 6.0, 40.3 ± 9.2, 12.53 ± 6.7, 14.0 ± 3.6, 74.6 ± 15.7, 11, respectively). The mean change in DBP was non-significant. **Conclusion:** Moderate-intensity downhill walk at −16% grade might be preferred for exercising individuals with a low tolerance to physical and cardiovascular stress.

KEY WORDS: Concentric Exercise; Eccentric Exercise; Lengthening Contraction; Rate Pressure Product; Shortening Contraction

INTRODUCTION

Systematic exercise is an essential component of the current guidelines published by various government agencies and professional organizations, for health promotion and improvement of the quality of life.[1-4] The American College of Sports and Medicine (ACSM) recommends at least 30 min of moderate-intensity aerobic exercise done 5 days a week, i.e., ≥150 min/week. Exercise bouts of 10 min are acceptable if the individual accumulates at least 20-60 min/day of daily aerobic exercise.[1] For Indian adults, recommended physical activity is 60 min every day, which should include at least 30 min of moderate-intensity aerobic exercises.[4] Treadmill walk is one of the most popular forms of indoor aerobic exercise.[5]

At a low gradient (slope), the work done by an individual for the downhill walk is less as compared to an uphill walk, due to the effect of gravity. However, the steeper negative slope requires the body to generate braking forces to prevent fall

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from the treadmill, thus increasing the physiological work in downhill walking. The mechanical efficiency of walking above +0.15 (uphill) and below −0.15 (downhill) grade is equivalent to those of concentric and eccentric muscle contraction, respectively.[6]

Concentric contraction causes shortening while eccentric contraction causes the lengthening of muscle as it exerts tension against the external load to move the bony lever. The weight of the person acts as an external load while walking on the treadmill.[7] Quadriceps will shorten during the uphill walk to cause the forward motion, while hamstrings will stretch or lengthen to slow down the forward motion during the downhill walk. Exercise that emphasizes on eccentric contractions (eccentric exercise) of skeletal muscles has recently gained attention due to its benefits over conventional exercise involving concentric muscle contractions (concentric exercise).[8]

"Feeling of exertion" either prevents a person from initiating an exercise session or results in drop-out from the training protocol;[9,10] hence, planning an exercise program that causes less exertion is imperative. A previous study reported that downhill walk at −10% grade results in lesser cardiovascular demands as compared to level treadmill walking.[11] Thus, the downhill treadmill walk can enhance physical well-being without causing undue cardiovascular and physical stress. It could be substantial for persons initiating an exercise program but have a low tolerance to the exertion.

There is a paucity of data on cardiovascular responses to an uphill and the downhill walk at ±15% gradient. The present study aims at comparing the acute effect of uphill (concentric exercise) and downhill (eccentric exercise) treadmill walk on physical exertion and cardiovascular stress in young sedentary individuals. Cardiovascular stress is evaluated by the rate pressure product (RPP) (product of heart rate [HR] and systolic blood pressure [SBP]), a noninvasive predictor of myocardial oxygen consumption.[12] Physical exertion is gauged by the Borg's rating of perceived exertion (RPE) (6-20 scale), which is based on the integration of somatic perceptions such as an increase in HR, respiratory rate, sweating, and muscle fatigue experienced by an individual during exercise.[13]

MATERIALS AND METHODS

The present non-randomized crossover study was conducted in the Exercise Physiology Laboratory of King George's Medical University, Lucknow, Uttar Pradesh, India, from February 2016 to September 2016. The Institutional Ethical Committee granted ethical clearance for conducting this study.

Sample Size

Sample size (n) was calculated by the G*power software v3.1.9.2 for Windows.[14] In a study, RPP calculated for young participants after concentric exercise was 209 ± 46 while after eccentric exercise was 151 ± 27.[15] Assuming 80% power, 5% significance level, and 50% correlation between the groups, calculated sample size was 9 if two-tailed paired t-test or Wilcoxon test is to be used. A convenient sample size of 30 was taken in the present study.

Inclusion Criteria

Apparently healthy individuals, aged 18-25 years, having a normal body mass index (BMI) of 18.5-22.9 kg/m^2 (as per Asia Pacific Classification of BMI by World Health Organization)[16] were involved in the study. All participants provided a written informed consent before enrollment in the study as subjects. "General practice physical activity questionnaire" (GPPAQ)[17] was used to analyze sedentary lifestyle. Inactive or moderately active individuals as per the GPPAQ were included in the study. Participant's fitness to do physical activity was analyzed by the physical activity readiness questionnaire.[18] "No" as an answer to all of the seven questions in the PAR-Q was an inclusion criterion.

Exclusion Criteria

Participants with a history of any known disease that might adversely affected their health and/or study results and any abnormality detected during the general and systemic examination that would have obstructed the safe performance of exercise tests were excluded from the study.

Participant's Characteristics

Participants' mean age was 20.6 ± 1.9 years, having height of 166.4 ± 5.8 cm, weight of 57.4 ± 5.5 kg, and BMI of 20.7 ± 1.4 kg/m^2.

Study Protocol

The study was divided into two phases. During Phase-1, all participants did an uphill treadmill walk. Phase-2 involved downhill treadmill walking. A gap or rest period of 2 weeks was given between the two phases, to eliminate any residual effect of uphill walking done previously. Each phase was comprised of three familiarization sessions before the test day, on which study parameters were recorded. Participants were instructed to avoid any strenuous muscular activity during the study period.

Familiarization sessions

Unaccustomed exercise is associated with delayed-onset muscle soreness, particularly when involving eccentric contractions.[19] Repetition of the same eccentric exercise reduces muscle damage known as the "repeated bout effect." A previous study has reported that a single familiarization session is sufficient to remove any muscle soreness for up to 6 months.[20] Hence, three familiarization sessions on an alternate day were conducted for an uphill as well as for the downhill walk, which made participants accustomed to the treadmill working and exercise methodology. Subjects were advised to wear comfortable, non-restrictive clothing and avoid heavy meals at least 2 h before the training sessions. "Pro Bodyline Fitness Treadmill 970" was used for the walk. For an uphill walk, treadmill slope was set at +0.16 grade (or 9° from the horizontal). Similarly, for the downhill walk, treadmill slope was set at −0.16 grade (or −9° from the horizontal). The slope was created manually by placing the treadmill on a wooden wedge.

The intensity of exercise was kept moderate to avoid muscle damage and residual soreness, by adjusting the speed of treadmill during the uphill walk. As per the ACSM recommendations, exercise intensity is moderate when the HR during exercise remains between 64% and 76% of the maximum HR (HRmax).[1] HRmax was calculated by the equation: HRmax = 208 − 0.7 × age in years.[21] "ChoiceMMed Pulse Oximeter MD300C20" was used for continuous monitoring of HR during the exercise. The speed of the treadmill during the downhill walk was kept same as during an uphill walk, for each participant. The average speed of the treadmill was 4.6 ± 0.4 km/h. Participants under the strict vigilance in a one-on-one environment completed all the sessions. It was ensured that each participant fully understood the Borg's RPE. Effect of circadian rhythm on cardiovascular variables was eliminated by performing all sessions between 2 PM and 4 PM only.

Test day

On the test day, participant walked on an inclined (for uphill) or a declined (for downhill) treadmill for three bouts of 10 min with a min of rest between each bout. "Omron HEM 7130" automatic blood pressure monitor, a validated machine to measure blood pressure in the range 0-299 mm Hg (±3 mm Hg) and HR from 40 to 180 beats/min. (±5% of display reading),[22] was used to record the following parameters just before and after the exercise:

a. SBP in mmHg (average of three readings was taken).
b. Diastolic blood pressure (DBP) in mmHg (average of three readings was taken).
c. HR/min.
d. Pulse pressure (PP) = SBP - DBP in mmHg.
e. Mean arterial pressure (MAP) = DBP + 1/3(SBP-DBP) in mmHg.
f. RPP = (SBP × HR) ÷ 100 in arbitrary units.

Evaluation of physical stress was done by registering the response of participants to Borg's 6-20 scale RPE, after completion of the exercise session.

The same investigator performed all anthropometric measurements. A calibrated digital weighing machine was used to measure the body weight to the nearest 0.1 kg. Height was measured to the nearest 1.0 cm without shoes by a rigid stadiometer. BMI was calculated as weight in kilograms divided by the square of height in meters.

Statistical Analysis

Primary data entry and calculations were done in Microsoft Office Excel 2016. Further statistical analysis was performed in IBM SPSS Statistics v24.0 for Windows (IBM Corp., Armonk, New York. Released 2016). Shapiro–Wilk test was used to analyze the normality of data distribution. Means with standard deviations were reported in the descriptive analysis of quantitative data, while median with 25th and 75th interquartile was reported for categorical data. Comparative analysis of within-group and in-between group data was done either by the paired samples *t*-test (for normally distributed data) or by Wilcoxon signed ranks test (non-normal data distribution). $P < 0.05$ was considered statistically significant. All values are rounded off to the nearest one decimal place.

RESULTS

No dropout was recorded in the study.

A non-significant difference in the cardiovascular parameters was obtained on comparing them before an uphill and the downhill walk (Table 1). Thus, the baseline cardiovascular variables were similar before each type of the walk. The elevation in SBP, DBP, HR, MAP, PP, and RPP was significantly more after an uphill walk as compared to the downhill walk (Table 2). However, the DBP was similar after both types of the walk. The absolute change (i.e., post-exercise value – pre-exercise value) in SBP, HR, PP, MAP, and RPP was significantly more after an uphill walk as compared to the downhill walk (Table 3). The absolute change in DBP after an uphill walk was similar to the absolute change in DBP after the downhill walk.

Table 4 shows the descriptive analysis of RPE after an uphill and the downhill walk. Uphill walk resulted in a significantly

Table 1: Comparison of baseline cardiovascular parameters before an uphill and downhill walk (*n*=30)

Parameters	Cardiovascular parameters (before)		*P**
	Uphill walk	Downhill walk	
SBP (mmHg)	121.0±3.3	120.9±3.3	0.698
DBP (mmHg)	78.5±3.7	78.5±3.7	1.000
HR (/min)	75.3±5.0	75.3±5.0	1.000
PP (mmHg)	42.4±3.6	42.5±3.6	0.756
MAP (mmHg)	92.7±3.2	92.7±3.1	0.856
RPP (AU)	91.2±7.1	91.1±7.2	0.867

*Paired *t*-test, P<0.05 is statistically significant. SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, PP: Pulse pressure, MAP: Mean arterial pressure, RPP: Rate pressure product, AU: Arbitrary units higher median value of RPE, as compared to the downhill walking.

DISCUSSION

The results of the present study show that the moderate-intensity downhill walk at −16% grade or eccentric exercise caused significantly less physical exertion and cardiovascular stress as compared to an uphill walk at +16% grade or concentric exercise in healthy, young individuals with a sedentary lifestyle.

The results of the present study are consistent with the reporting of the previous studies that have compared the eccentric exercise with concentric exercise for cardiovascular response.[11,15] However, due to wide variation in subject characteristics, training/exercise modalities, and protocol as well as measurement techniques, it is tough to compare our results directly with that of the previous studies.

The eccentric muscle contractions result in less cardiovascular and physical stress than the concentric muscle contractions due to the different mechanisms involved in these two types of muscle movements.

The "sliding filament theory"[23] has been a dogmatic explanation for muscle contraction, but it has difficulties in accurately predicting the force and energy efficiency of eccentric contractions. Several theories have been put forth to explain the mechanism of eccentric contractions. Non-adenosine triphosphate-dependent mechanical rupture of actin-myosin cross-bridges could explain the lesser energy utilization in an eccentric contraction relative to concentric contraction.[24] Stretch on the muscle before contraction causes a widening of I-band in sarcomere; hence, actin-myosin cross-bridges cover a longer distance in an eccentric contraction resulting in greater force production as compared to the concentric contraction.[25] The proposed action of titin in the new "three-filament model of muscle contraction," in conjunction with the actin-myosin-based cross-bridge theory, accurately predicts the physiological properties of an eccentric skeletal muscle contraction.[26] According to a recent view, the lesser recruitment and discharge rate of motor units during an eccentric contraction relative to a concentric contraction performed with the similar absolute workload explain the energy efficiency of an eccentric contraction.[27]

The greater force production with less energy involvement would produce less stress on muscles, thereby reducing nutrient and oxygen requirement during an eccentric contraction as compared to a concentric contraction. Lower the metabolic demand of the exercising muscles lesser will be the stress on the cardiovascular system.[28] Hence, the downhill walk that involved eccentric contractions resulted in lesser cardiovascular response than an uphill walk. RPP, an index of myocardial oxygen consumption,[12] was significantly less after downhill than uphill walk, further indicating the lesser cardiovascular stress during eccentric contractions. RPE enables a person to evaluate how hard or easy an exercise felt by collective integration of feed-forward mechanisms and afferent feedback from cardiorespiratory, metabolic, and thermal stimuli.[13] A significantly low RPE response of participants to downhill than uphill walk further strengthens that lower cardiometabolic demand occurs in the eccentric contractions.

Table 2: Comparison of cardiovascular response after an uphill and downhill walk (n=30)

Parameters	Cardiovascular response (after)		P*
	Uphill walk	Downhill walk	
SBP (mmHg)	147.7±6.4	143.2±6.9	0.0001
DBP (mmHg)	89.0±5.6	88.7±5.9	0.163
HR (/min)	133.5±8.4	115.6±9.6	0.0001
PP (mmHg)	58.7±6.6	54.5±7.2	0.0001
MAP (mmHg)	108.6±5.0	106.9±5.3	0.0001
RPP (AU)	197.4±17.5	165.7±18.1	0.0001

*Paired t-test, P<0.05 is statistically significant. SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, PP: Pulse pressure, MAP: Mean arterial pressure, RPP: Rate pressure product, AU: Arbitrary units

Table 3: Comparison of absolute change in cardiovascular parameters after an uphill and downhill walk (n=30)

Parameters	Absolute change (post-exercise-baseline value) in parameters (after)		P*
	Uphill walk	Downhill walk	
SBP (mmHg)	26.7±5.6	22.3±6.0	0.0001
DBP (mmHg)	10.5±4.7	10.1±5.3	0.250
HR (/min)	58.2±6.8	40.3±9.2	0.0001
PP (mmHg)	16.2±6.1	12.0±7.3	0.0001
MAP (mmHg)	15.9±4.1	14.2±4.2	0.001
RPP (AU)	106.3±14.5	74.6±15.7	0.0001

*Paired t-test, P<0.05 is statistically significant. SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, PP: Pulse pressure, MAP: Mean arterial pressure, RPP: Rate pressure product, AU: Arbitrary units

Table 4: Descriptive statistics and comparative analyses for RPE after the uphill and downhill walk (n=30)

Parameter	Uphill walk			Downhill walk			P*
	Median	25th percentile	75th percentile	Median	25th percentile	75th percentile	
RPE	12.5	12.0	13.3	11.0	10.0	13.0	0.0001

*Wilcoxon test, P<0.05 is statistically significant. RPE: Rating of perceived exertion

A recent study has reported that downhill walk resulted in an increased total peripheral resistance and hence DBP, compared to level walking.[11] However, comparison of the DBP after an uphill walk to that of a downhill walk yielded a statistically non-significant result in the present study. In addition, compared to some of the previous studies,[11,15] accentuated HR and slightly lower SBP response was obtained in our study. "Cardiovascular drift" phenomenon can explain the variation in HR, SBP, and DBP reported in our result. Exercise performed for more than 15 min in the hot ambient temperature causes sweating which produces water loss and a fluid shift from plasma to the tissues. A rise in core temperature also redistributes blood to the periphery for body cooling. The fall in plasma volume decreases venous return, which in turn reduces stroke volume (SV). A reduced SV causes a compensatory HR increase to maintain a nearly constant cardiac output. The term cardiovascular drift describes the gradual time-dependent downward "drift" in several cardiovascular responses, most notably in HR (positive drift), SBP (negative drift), and TPR (negative drift).[29]

Adolf Fick did one of the first research observations with eccentric muscle actions in 1882.[30] In spite of an old concept, emphasis on the eccentric contraction of large muscle groups as in downhill treadmill walk could emerge as a new or updated exercise modality. The downhill walk is characterized by specific mechanical and cardiovascular properties that facilitate its applications in various settings where the ultimate objective is to improve the quality of life without causing undue cardiovascular and physical stress on an individual.

The strength of the study is a crossover design wherein each participant acted as their control, and each participant performed both types of the walk, thus streamlining the chances of confounders and biases. A major limitation of this study is that the participants are healthy individuals; hence, the study results may not apply to the mass population. Future studies involving individuals suffering from cardiopulmonary insufficiency or any other debilitating illness seen in the general population would increase the external validity of the study result. In the present study, young males were involved; the results may vary across different gender and age groups. An acute exercise bout was done in the present study; the results may vary after a long-term training. Large sample size involving different age groups and gender with a long duration of the exercise training protocol will increase the accuracy of data.

CONCLUSION

Our results suggest that moderate intensity downhill walking could be used as an option for exercising the persons having a low tolerance to exertion. Future studies are warranted on whether downhill walking is suitable for deconditioned individuals.

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