Men's Health Journal. 2020; 4(1): e5

OPEN ACCESS

ORIGINAL RESEARCH

Effect of excessive Arm Swing on Speed and Cadence of walking

Razieh Yousefian Molla[1], Heydar Sadeghi[2*], Farzam Farahmand[3], Mohammad Ali Azarbayjani[4]

1. PhD Sports Biomechanics, Department of Sports Physiology and Biomechanics, Central Tehran Branch Islamic Azad University, Tehran, Iran.

2. Professor, Department of Sports Biomechanics, Kharazmi University, Tehran, Iran.

3. Professor, Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran.

4. Professor, Department of Sports Physiology, Central Tehran Branch Islamic Azad University, Tehran, Iran.

Received: March 2020; Accepted: April 2020; Published online: May 2020

Abstract: **Introduction:** One of the changes in the movement patterns that can be seen in upper limb swing is the excessive increase in upper limb movement and swing during walking. As temporal parameters such as cadence and speed in stationary and mobile environments can be equally used to determine early fall potentials, Therefore, this study aims to investigate the effect of excessive arm swing on speed and cadence of walking. **Methods:** 30 healthy subjects were exposed to Vicon 10 motion capture system analysis and were asked to first walk normally at normal speeds and then move their hands excessively while walking at the same speed. The temporal data were extracted and analyzed by Matlab software. Descriptive (mean, SD) and Shapiro-Wilk test for normality of data distribution, and paired sample t-test were used to compare the patterns. **Results:** there was a significant difference in cadence and speed variables, between the means of natural arm swing and excessive arm swing modes ($p \leq 0.05$). **Conclusion:** Given these results, it should be considered that the effects of upper limb pattern changes on the lower limbs and gait can compensate for the lack of attention to movement and pattern of upper extremity positioning during walking.

Keywords: arm swing; speed; cadence; walking

Cite this article as: Yousefian Molla R, Sadeghi H, Farahmand F, Azarbayjani M A. Effect of excessive Arm Swing on Speed and Cadence of walking. Mens Health J. 2020; 4(1): e5.

1. Introduction

During normal human walking, the hands tend to be suspended opposite to the legs (1). In this process, with the pelvic belt rotating counterclockwise on the left foot stance, the shoulder girdle rotates opposite to the pelvic belt. Studies show that by transferring the pelvic rotation to the body, the rotational motion of upper limbs will be eliminated and the movement in this part manifests itself as flexion and extension (2).

During walking, the occurrence of arm swings has important effects and many biomechanical interventions that appear on the lower limbs, as it has been proven that the effects of rhythmic oscillation in the upper limbs occur as an interaction between the hands, legs, and trunk during walking (3, 4). It is evident nowadays that, during walking, the components of the ground reaction force and the path of the center of mass of the whole body are affected by changes in hand movement and walking speed, and by minimizing trunk movements, vertical fluctuations in the body's center of mass will decrease and subsequently impact energy consumption will occur (5, 6). Therefore it is concluded that due to reduction of vertical body mass transfer, reduction of angular momentum or ground reaction force momentum (7, 8), the presence of oscillation in the upper limbs, causes the body to consume less energy while walking (9, 10) and this is followed by the increase of walking balance and post-disturbance balance restoration (8, 11), postural control (7, 12), body rotational stability (12), and lateral balance maintenance (13), thereby reducing the body's neuromuscular efforts to maintain balance (14, 15). On the other hand, given the above-mentioned interactions of the upper limbs on the

*Corresponding Author: Heydar Sadeghi, Address: Department of Sports Biomechanics, Kharazmi University, and Tehran, Iran. Email: sadeghih@yahoo.com

lower limbs, various studies have been carried out but with many theories regarding the kinetic, kinematic and spatio-temporal effects of upper limb swing on walking and lower limbs. In some of these studies, it has been reported that changes in the oscillation and movement pattern in the upper limbs cause changes in the step width (16), step length, step frequency, walking rate and velocity (17-19), the force applied to the lower limb joints (20) and even has significant effects on VO2MAX, heart rate and oxygen consumption (3).
One of the changes in the movement patterns that can be seen in upper limb swing is the excessive increase in upper limb movement and swing during walking. For example, researchers suggest that a person with a stroke generally moves his or her non-involved arm while walking more than the involved arm (21), and this arm usually follows a reciprocal pattern (22), While his affected hand represents an altered and alternate coordination between the limbs (21) Or there is research that suggests, older people are likely to have more arm swing while walking (23). Few studies have been conducted on the effect of the excessive increase of arm swing while walking, on its important variables such as speed and cadence of walking. Some of these studies are mentioned below.
Fays et al. (2011) (24) were among the researchers who investigated the effect of hand throwing on temporal parameters of walking in stroke patients, They randomly selected 23 stroke patients diagnosed as having a cerebrovascular injury to be evaluated in this study. Three-dimensional walking data were collected using QUALISYS ProReflex kinematic analysis system and temporal parameters including walking speed, cycle time and cadence were measured. The results of their study showed that when walking with throwing their hands, patients' cadence and speed of walking have increased. In 2015, Pant et al (25) examined, how fast hand movement affects stability and walking speed. In that study, they selected ten healthy, adult male volunteers. The results showed that increasing hand movement on the mediolateral axis increased walking speeds compared to normal hand movement. Yuvo et al. (2016) (26) investigated the effects of hand movement on the variability cadence and speed under normal and excessive hand movement. They researched 24 healthy adults and found that velocity was significantly lower than normal values for normal hand motion under the two-arm override condition.
Given all the above, with regard of these outspread studies it should be borne in mind that during walking, temporal parameters such as cadence and speed in stationary and mobile environments can be equally used to determine early fall potentials (2, 25, 27) and to record walking disorders and changes related to rehabilitation (28, 29). It also provides accurate temporal assessments during walking, demonstrates a good understanding of health and proper motor control, and exhibits proper walking analysis. Therefore, this study aims to investigate the effect of excessive arm swing on speed and cadence of walking.

2. Material and Method

Thirty healthy subjects aged 20-40 years were recruited by convenience sampling method to participate in this study. Written consent was obtained from all participants in the present study and all of them were fully informed about the stages of the study. Then, initial primarily assessments were performed by personal information and physiological health (cardiorespiratory condition), anthropometric status (lower limb and upper limbs measurements), and musculoskeletal abnormality (any lower limb abnormality) evaluation. Subjects were excluded if they had a history of injury and orthopedic, neurological, respiratory or cardiovascular diseases, any postural abnormalities, surgical history, or mental disorders that may influenced on their gait. Subjects were then exposed to Vicon 10 motion capture system analysis (120 Hz made in the UK, Nexus software filter woltring, Mode MSE) using the plug-in gait marking method of passive markers and were asked to first walk normally at normal speeds and then move their hands excessively (move too rapid) while walking at the same speed. Walking procedure were done, barefoot in 4 trials (4 gait cycle), and in the end, the kinematic and temporal data related to the rate and speed of the movement were extracted and analyzed by Matlab software.
Descriptive statistics were used to analyze the data to calculate the mean, standard deviation and Shapiro-Wilk test for normality of data distribution. Then inferential statistics and paired sample t-test were used to compare the pattern of excessive hands movements with normal arm swing to compare the cadence and speed variables. Statistical analysis was performed by SPSS version 22 and $p \leq 0.05$ was set as the level of statistical significance.

3. Results

In table 1-1 Descriptive statistics of the participants in this study are shown. Considering that the main purpose of this study was to investigate the effect of excessive arm swing on walking rate and speed, we attempted to collect fundamental information related to the physical factors of the participants to uniform the measured samples, which are presented in Table 1-1. Shapiro-Wilk test was used to check the normality of the data distribution and the results showed that the data distribution was normal in all variables of the study. After using a paired sample t-test to make sure that the distribution of data was normal, the results of walking rate and speed parameters were compared and analyzed in the two conditions of excessive arm swing and normal posture, the results are presented in Table 2-1 ($p \leq 0.05$). Based on the results of

Table 1: Individual Indicators of Research Subjects (Mean ± SD)

Variable	Mean ± SD	Variable	Mean ± SD
Age(year)	29.56 ± 3.5	Weight(kg)	64.2 ± 6.29
Height(cm)	163.36 ± 6.08	BMI(kg/m^2)	24.06 ± 3.25
Length of leg(cm)	22.23 ± 1.75	Length of Lower Limb	87.63 ± 12.56

Table 2: Paired t-test results for comparing the measured levels of cadence and speed of walking variables in excessive Arm Swing (p≤0.05)

Variable	Pattern	Mean	SD	T	P
Speed of walking(m/s)	Normal Arm Swing	0.88	0.15		0.001*
	excessive Arm Swing	1.02	0.17	-3.91	
Cadence(steps per minutes)	Normal Arm Swing	100.48	2.25		
	excessive Arm Swing	114.42	2.74	-5.28	0.000*

*Significant in p≤0.05 level

Table 2-1, there was a significant difference in cadence and speed variables, between the means of natural arm swing and excessive arm swing modes. According to these results, excessive arm swing during walking resulted in an increase in both of these variables compared to the normal condition.

4. Discussion

This study aimed to investigate the effect of excessive arm swing on the walking speed and cadence variables. As observed in the section of results (Table 2-1), there was a significant effect on walking speed and cadence variables following excessive arm swing (p≤0.05). The significant results of these objectives were in line with the studies of Collins (10) , Maud (27) and Pant (25). In the studies conducted by and Maud (27), despite the physiological approach of the two studies, with increasing the movement of hands, walking temporal variables such as speed increased, similar to the present study. Because the ground reaction force while walking through the legs is transferred with the body and then to the upper extremities, it may be concluded that increased speed of movement of the upper limbs causes the transmission of upper limb force through the above chain to the lower limb and increase of the temporal variables in it. This pattern may be beneficial for people who lack the ability or skill to increase the speed or enhance temporal variables for different reasons and have orthopedic, neurological, or structural problems for some reason and useful to increase the quality and level of aerobic exercise.
Moreover, this consistent effect was also observed in the study performed by Pant (25). Because walking cadence is the number of steps a person travels in a minute, so maybe we can say that the amount of stability generated in each of the legs rises equally when walking during excessive arm swing because the increase in walking cadence represents a further step that a person can walk to maintain balance and, due to the temporal variables, this is justifiable.
Thus, it may be concluded that increasing the movement of hands and generating the intervention in upper extremities may be a way to increase the speed and pattern for patients, athletes, or people who have low speed in walking or wish to increase their speed for any reason.

5. Conclusion

Based on the present study, the pattern of excessive arm swing affects the speed and cadence of walking and leads to increase it. Given these results, it should be considered that the effects of upper limb pattern changes on the lower limbs and gait can compensate for the lack of attention to movement and pattern of upper extremity positioning during walking so that the impact of these patterns on rehabilitation exercises, sports and rehabilitation along with efficient use of energy to be determined, and it causes the improvement in the quality of walking and the quality of life in healthy and diseased individuals and groups.

6. Appendix

6.1. Acknowledgements

This article is based on a Ph.D. thesis by Razieh Yousefian Molla in the field of sport biomechanics. Thereby, we thank and appreciate all the professors who helped us in conducting the present study.

6.2. Author contribution

All authors have same contributions.

6.3. Funding/Support

All authors declare that this study was composed with any funding or support.

6.4. Conflict of interest

The author declare that is no conflict of interests regarding the publication of this paper.

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