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Investigating the relation of walking speed changes with the metabolic energy consumption index in traumatic unilateral below knee amputees

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ABSTRACT

The purpose of this study was to investigate the relation between the walking speed changes and the metabolic energy consumption indexes in traumatic unilateral below knee amputated individuals participants included twenty four male unilateral traumatic BKA and twenty four(24) normal adults. Some of the data was collected through a questionnaire form and an electronic treadmill was used to yield the data about heart rate at walking and calories burnt at a given time. The BKA group and the normal group walked with three constant speeds of slow, medium and fast on the treadmill for 6 minutes and the heart rate, physiological cost index (PCI) and energy consumption (Kcal) were estimated at each speed. The result shows that relationship between changes in gait speed and each of indicators of the energy expenditure [heart rate, physiologic cost index (PCI) and energy consumption was linear in BKA group, just as it is in normal group, but the slope is significantly steeper. Student's t-test results indicated that the mean of each of the indicators of energy expenditure was significantly higher in BKA group and that with increases in gait speed, the difference between this group and normal subjects increased proportionately. In this study, the correlation between length of residual limb (cm) and heart rate at walking was significant (P<0.5); but there was no meaningful correlation between PCI and calories burnt per elapsed time and length of residual limb. The results suggest that the below knee amputated individuals with walking speed changes compared to normal speed, bare more physiological weight than the healthy individuals.

Key words: Metabolic Energy Consumption Index, Heart rate, Physiological Cost Index, Below Knee Amputee, Walking Speed

INTRODUCTION

One of the notable problems of amputees is the higher level of energy consumption during walking, compared to healthy people [8]. For instance, walking assisted by a below knee prosthesis, increases the body's energy needs up to 30 percent [9]. Generally, the total energy consumption during walking in traumatic below knee amputees is 25 percent higher than the normal people, and their movement speed is lower than that of the normal people, by 13 percent [9].

If under the influence of some factors such as the heavy weight of prosthesis, its wrong direction, inadequate suspension and the inconsistency among the dimensions and the volume of stump and prosthesis's socket, the amputee does not feel alright while walking and compensate the mentioned factors by more and longer muscular activity, the energy consumption exceeds the standard and predictable amounts, the heart will work throughout the movement time, will more rates and higher volumes of outcome. This issue if exists chronically for a long time, can lead to the individual's lifetime shortening. Using more energy, in addition to imposing an extra physiological weight on the body's cardiovascular system, causes the kinetic power decline, early fatigue, moving speed decrease and less covered distance by the individual. Also, it is possible to prevent the person from having similar experiences to healthy people, which consequently lowers the life quality of the person [10]. As a result, the person may be socially, economically and psychologically vulnerable.

By conducting this study, we wanted to compare young traumatic below knee amputees with the same age range of healthy people in case of energy consumption in three different speeds, and therefore we would obtain a criterion for comparing the prosthetic service quality in Iran with the world standards. The results can reveal the necessity of paying more attention to the anatomical and biomechanical principles in manufacturing the prostheses and the new approaches and components which decrease the energy need during walking [1].

MATERIALS AND METHODS

This study was done by a temporary descriptive-analytic approach. The population included 24 knee amputated individuals, aged 20 to 40, who had walked for at least 6 months, by means of PTB rigid foam below knee prosthesis, and had gone to one of the state's technical orthopedic clinics in order to repair the previous prosthesis or for receiving new prostheses. In order to compare the results, 24 healthy men within the same age range, were also included in the study. The sampling method was a random one, in this way that from the beginning of research administration, each below knee amputee went to aforementioned clinics , and if he had the required qualification for the study and if he was interested, he would be called up for participating in the study and information registering afterwards.

In this study, in order to estimate the metabolic energy during walking, two indirect indexes were taken into consideration, which can be regarded as reliable estimations of muscular effort and also the consumed oxygen amount while movement. These two indexes are heart rate and physiological cost index (PCI) of walking. Also, the treadmill used in the research, would present an estimation of the consumed energy amount (per kilocalories) during a certain time limit, when a person with a certain weight walks on it, which was also taken into consideration.

Instruments

The instruments used for collecting the data included a treadmill, a digital barometer for measuring the blood pressure in resting status, a mechanical scale, and a cloth tape measure. The in-person questionnaire was also used filled in by a technical orthopedic expert.

Data Collection Approach

In this research, in order to enact the three different speeds (slow, normal and fast), also for estimating the energy consumption amount, a RunTech 500 treadmill was used. For collecting and registering the individual data, an in-person questionnaire was also used.

For registering the data, firstly every subject would practice enough the walking style on the treadmill in order to keep the necessary balance and also to get accustomed to walking with three different speeds. Then, the three slow speed (33.34 m/m), normal (50 m/m) and fast (66.67 m/m) were enacted to the treadmill and in each speed, the person would walk for 6 minutes, that the first two minutes was considered for warm-up and also for reaching a steady status of heart rate and breath speed, and the data was recorded in the last 4 minutes. Before increasing the speed and beginning the new test, to reduce the effect of the fatigue caused by the previous test, the person would relax for at least 5 minutes. Furthermore, in each stage of the test, the heart rate was measure before beginning to walk on the treadmill (resting status) and after the 6-minute walking by the tester and the data was used for calculating the physiological cost index of the person in the three speeds.

Research Main Variables

Independent variables: these included the walking speed (m/m) , chronological age of the person at the time of testing (year) , body mass index (kg/m^2) , the length of the below knee stump (cm), blood pressure (mmHg) , the years of walking with prosthesis, and the heart rate at the resting status (beat per minute).

The dependent variables of the study were the amount of consumed energy during walking or running per calorie or kilocalorie, the heart rate in walking status and the physiological cost index (beat per meter).

The collected data was analyzed by the version 10 SPSS software, and the statistical tests such as Pearson correlation coefficient, student's t-test and chi-squared test, one-way analysis of variance and the correlation test of general linear model were used.

RESULTS

Demographic data description

Table 1: Cause of Amputation

Cause of Amputation	Number	Percent
Car Accidents	8	33.3
War	11	45.8
Industrial Accidents	5	20.8
Total	24	100.0

Table 2: Demographic and Clinical Variables

Variable	Number	Min	Max	Mean	SD
Years Since Amputation	24	1.5	25	13.72	6.77
Years since of using prostheses	24	0.58	23	12.60	6.52
below knee stump length(cm)	24	10	41.5	20.4	8.6

Table 3: Subject characteristics of Amputees and Control Group

Characteristic	Amputee	Nondisabled	p-Value*
Age	33	29.3	0.07
BMI	25	23.7	0.24
Heart Rate (rest)	82.2	78	0.212
Normal walking speed	57.90	66.84	0.002

**Student's t-test*

Table 4: Correlation between PCL, Heart rate, EC in different walking speed

Variable	Speed	Group		Paired t Test		Correlation	
		Amputee	Control	t	P	r	P
PCL (beats/m)	Slow	0.771	0.603	1.99	0.026	- 0.305	0.901
	Medium	0.607	0.463	2.45	0.018	- 0.373	0.909
	Fast	0.605	0.455	2.65	0.011	- 0.460	0.753
HR (beats/Min)	Slow	107.9	98.1	2.26	0.028	- 0.411	0.046
	Medium	112.5	101.2	2.72	0.009	- 0.455	0.026
	Fast	122.5	1.8.3	2.91	0.005	- 0.521	0.009
EC(Kcal)	Slow	14.41	12.75	2.19	0.033	0.027	0.901
	Medium	21.65	19.37	2.05	0.045	- 0.025	0.909
	Fast	29.28	25.91	2.25	0.029	- 0.068	0.753

DISCUSSION

In the present study, it was determined that between the walking speed changes and each of the discussed energy indexes, there is a meaningful relation and the results of the below knee amputee group is comparable to the results of the healthy group. However in the amputee group, the mean difference of each index in different speeds is higher than what is observed in the control group. In other words, by increasing the speed, the walking energy costs in the amputee group intensifies. The claim above is in accordance with the results of Molen's study (1973). He has explained in the study that although the relation between walking speed and energy consumption during walking with prosthesis – exactly similar to what happens in the normal people- is a linear one, the slop of the line for the amputee group, is considerably higher [10]. The clinical meaning of the relation above is that the energy consumption amount and the heart activity in any speed, is higher in the amputee group, and also that the transfer threshold from the aerobic oxidation to anaerobic metabolism is in the lower speeds.

The consumed energy mean (kilocalorie) in the amputee group throughout the walking time on the treadmill was 6 percent higher than the healthy group. Also in the amputee group, the heart rate mean was 5.5 percent and the PCI mean was 13 percent higher than those of the healthy.

Shurr (1990) claimed that the oxygen cost – that is the consumed oxygen volume per the covered distance- in the below knee amputees is 28-33 percent higher than that of the normal [9]. In a study by Schmalz (2001), in order to investigate the effect of various approaches of prosthesis direction adjustment and the effect of the prosthesis's components' type on the oxygen consumption amount and other biomechanical features of lower limp amputees' walking, there is this note that the below knee amputees' oxygen consumption with the similar walking speeds, is 25 percent higher than the normal people [19]. Kumar (1982), also reported that the unilateral below knee amputees, consume 9-20 percent more energy than the healthy people [6].

However beside these the two conclusions above, it will be proper to consider another researcher's claim on the subject. In a study done by Waters et al (1996), it was determined that in the young adults suffering from traumatic trans-tibial amputation, the oxygen consumption amount in the unit of time and the oxygen cost per the covered distance are near to the corresponding amounts in the normal people [10]. Considering that the present study has been done with the participation of unilateral below knee amputees aged 20 to 40, the results of this study is more compatible with the Waters's findings.

In this study, it was determined that the heart rate shows a meaningful and inverse relation with the below knee stump length in all the three speeds of walking, in such a way that by increasing the below knee stump length, the heart rate decreases during the walking action [Table 4].

The physiological cost index also showed a meaningful and inverse relation with the below knee stump length, only in the status of walking with the fast speed, but in none of the speeds, a meaningful correlation between the below knee stump length and consumed kilocalorie of energy was observed.

In a study conducted by Gailey et al (1994), also no meaningful relation was observed between the walking energy cost and the below knee stump length, though by classifying the remaining limb length to short , average and long stumps, a slight but meaningful difference was observed in the energy costs to the benefit of the long stump [22].

In the present study, no meaningful correlation was observed between the heart rate or the physiological cost index and the body mass index and there was no contradiction in this case between the two study groups. This conclusion is not compatible with the findings of Mattson's study (1997), since he reported a meaningful correlation between the BMI and the heart rate during walking [30]. But in case of correlation of the PCI and the BMI, the results of the present study are in accordance with the findings of Peebles et al (2003). They also did not determine any meaningful relation between the BMI and PCI during walking on the treadmill or on the ground, by using regression analysis test [31].

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