Original Article

Effect of Shoulder Pain on Energy Expenditure among Paraplegic Individuals: Role of Wearable Device

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Abstract

Background: Human interactive wearable devices are cutting-edge technologies transforming the health-care system by allowing comfort, convenience, and continuous patient monitoring. Wheelchair use in spinal cord injury is the best form of mobility. Shoulder pain is often the consequence to increased kinetic demands placed on the upper limb. This paper is an endeavour to determine the effect of shoulder pain on energy expenditure amongst manual wheelchair users with an amalgamation of physiological health parameters and advancement in health monitoring technology. **Methodology:** Forty paraplegics using manual wheelchairs were divided into two groups depending on the presence of shoulder pain. Shoulder pain characteristics were noted using the Wheelchair Users Shoulder Pain Index. Mean heart rate during 6 min propulsion test was determined using the Xiaomi MI fitness band. Physiological Cost Index was established, and the energy expenditure was then compared. **Results:** Shoulder pain was reported maximum during pushing the wheelchair >10 min (80%) and on-ramps (65%). The energy expenditure showed a statistically significant increase in patients with shoulder pain. **Conclusion:** The use of Xiaomi MI fitness band is a straightforward and affordable way to obtain the mean exercise heart rate assisting in estimating the energy expenditure. Shoulder pain significantly increases the energy expenditure among manual wheelchair users, and hence should be addressed before wheelchair use for the prevention of injuries.

Keywords: Energy expenditure, manual wheelchair users, MI fitness band, physiological Cost Index, shoulder pain, spinal cord injury

Introduction

Spinal cord injury (SCI) is a catastrophic condition that, depending on its severity, may cause dramatic changes in a person's life. The incidence of SCI varies from 9.2 to 56.1/million worldwide with its prevalence in India being approximately 1.5 million. The nature of the injury and the functional status of the individual depends on the location and the severity of the damage caused.[1-3] A person with SCI uses a wheelchair for their activities of daily living. A wheelchair serves as the primary channel for mobility and enables the individual to live independently with minimal dependency. There are numerous types of wheelchair available worldwide, the most commonly used being the manual wheelchair, which has to be self-propelled. A huge majority of the SCI population in India uses a manual wheelchair on account of its cost-effectiveness.

In paraplegics, wheelchair enables them to do various activities in comparison to an abled bodied individual. The manual wheelchair has to be propelled to diverse locations requiring the activation of several muscles of the upper limb. Many wheelchair users experience upper-extremity pain that interfere with essential daily activities of living such as wheelchair propulsion, driving, dressing, and transfers. However, the competing mobility and stability demands on the shoulder girdle and the intricate structural and functional design result in the shoulder complex being highly susceptible to pain, dysfunction, and instability.

Energy consumption for a number of activities in individuals with SCI is different than able-bodied individuals. The most

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commonly used physiological parameter for the assessment of energy expenditure has been the measurement of oxygen uptake. The traditional method of calculating energy expenditure is using the COSMED device. This device is expensive and is not easily accessible in clinical settings. This method, however, has been observed to be impractical during rehabilitation in clinical situations. Both speed and heart rate have been used as indicators of efficiency and energy cost of locomotion, but their combined use was first reported by MacGregor in 1979, who highlighted the problems of factors other than workload which may cause heart rate variability. He introduced an easier method of finding the energy expenditure, and it was termed as the Physiological Cost Index (PCI).[4,5]

Body sensor devices, fitness trackers, and wireless technologies are the cornerstones to health informatics. These novel health monitoring and wellness tools provide accurate and real-time measurement of physiological parameters boosting the health-care system and thus enhancing the quality of life.[6] Body-worn sensors or wearable gadgets chiefly dominate the fitness-detecting market, which use global positioning system receivers to connect to discrete devices like the smartphones.[7,8] Vital parameters such as heart rate, pulse, and oxygen levels are monitored and recorded closely along with fitness activity, and sleep pattern . through the use of wireless smart trackers and smartphones enhancing the health-care systems.[9,10] Overall health and physical activity are determined by the precise estimation the energy expenditure making wrist-worn heart rate and fitness monitors extremely trendy and well accepted.[11-14] These fitness trackers calculate the heart rate using specialized sensors during exercise and are paired with the user's smartphone making them accessible in clinical settings and cheaper than the traditional methods. The Xiaomi Mi Band 2 is one of the cheapest and the easily available brand in the market.[7] Thus, with the help of this device, the heart rate can be identified, and in turn used to analyze the energy expenditure using PCI making it easier to determine the energy expenditure among manual wheelchair users and also analyze the effects of shoulder pain on energy expenditure.

Methodology

The ethical approval was obtained from the Institutional Review Board before the commencement of the study. SCI rehabilitation centers around Mumbai and Navi Mumbai area were identified and the patients visiting these institutions were approached for participating in the study. After obtaining written informed consent, 40 patients within 18–50 years of age, diagnosed with SCI below T6 level in accordance with the ASIA Impairment Scale were included in the study. These patients were using manual wheelchair at least for the past 3 months as primary means of mobility. Patients with any injuries, recent fractures or deformities in the upper limbs, and cardiorespiratory dysfunctions were excluded from the study. The Wheelchair user's Shoulder Pain Index (WUSPI) was used to assess shoulder pain among the patients and were then divided into two groups – Group A – Patients with Shoulder Pain ($n = 20$) and Group B – Patients without shoulder pain ($n = 20$).

WUSPI: is a reliable and valid self-reported tool for the measurement of functional cost of shoulder pain among wheelchair users. It is a 15-item instrument measuring shoulder pain during four subsections that is, wheelchair transfers, wheelchair mobility, self-care, and general activities using visual analog scale. The individual item scores are then aggregated for obtaining the total index score.[15]

A 6 min propulsion test (6MPT) was then performed to assess the cardiovascular fitness of the patients. The blood pressure and respiratory rate were noted. The blood pressure cuff was tied on the left upper arm and secured. The patient was instructed to propel the wheelchair briskly around the marked area of 30 m between two cones and continue doing the same for 6 min. The number of laps completed was counted, and the distance covered was noted. The propulsion speed was then determined.[16]

The Xiaomi MI Band Version 2 was secured in the right wrist. The Mi Fit application was downloaded on the investigator's smartphone and was paired to the band to record the mean heart rate throughout the test for each participant.

After the test completion, the time taken for the blood pressure, heart rate, the respiratory rate, to come back to baseline was noted to ensure adequate cardiovascular functioning. The rate of perceived exertion using Modified Borg's Scale was noted posttest.

Energy expenditure was calculated using PCI from the mean heart rate recorded in Mi fit application using the formula:

$$\text{PCI} = \frac{\text{Mean exercise heart rate} - \text{Resting heart rate}}{\text{Propulsion speed}}$$

The data thus collected were tabulated in Microsoft Excel and analyzed using SPSS software Version 24 (IBM Corp., Armonk, NY). The normality of the data was analyzed using Shapiro–Wilk's test. The data were found to be freely distributed, and Mann–Whitney U-test was used for comparison between the two groups.

Results

The study discovered that the majority of the patients were males and were using the wheelchair on an average of 5–6 years. Among other activities, most of the shoulder pain was noted while pushing the wheelchair, followed by going uphill and sleeping on the side. We also noted an increase in the energy expenditure on comparison.

Discussion

The current awareness regarding fitness and active lifestyle has piqued the consumer interest leading to designing and manufacturing of various health monitoring devices. The advancement of technology in the past few decades, has

produced sensors and electronics with complex and miniature designs that can be used for "biometric monitoring." These wearable devices generate data that can be potentially used in health care and clinical setups as they are associated with minimum invasive methods and cost-effective procedures.[13,17] Thus, the idea that wearable technology can aid in enhancing the assessment of energy expenditure in SCI patients was explored in this study.

The physiognomies of the patients recruited in the study are described in Table 1. Patients with SCI have listed shoulder joint pain as the most frequent secondary complaint. The prevalence reported for the same is around 36%–71%. The study witnessed shoulder pain mainly during pushing the wheelchair for >10 min (80%), pushing up the ramp or inclines outdoor (65%), and sleeping on the side (60%) on evaluation with the WUSPI scale. The quality of life and social participation of individuals with SCI are tremendously influenced by the dependency on their upper extremities for daily activities as well as mobility. Manual wheelchair use relies mainly on the integrated function of the shoulder complex, thus, rendering it vulnerable to pain and injury. The following upper limb activities performed by these individuals are commonly related to shoulder pain – wheelchair propulsion, transfers, and activities involving depression pressure and associated relief raise. These activities are implemented multiple times throughout the day resulting in higher shoulder forces. Although propulsion requires reduced forces, the frequency of propulsion throughout the day is larger making this one of the most frequent activities, resulting in shoulder pain.[18,19]

During propulsion on the ramps, the stresses on the shoulder and shoulder girdle muscles are high and unevenly distributed owing to maximal contractions of rotator cuff muscles, pectorals, and scapular stabilizers, thus, making this the second other activity leading to shoulder pain.[20,21]

The shoulder complex is thus, used continuously for weight-bearing and propulsion activities. This poses a biomechanical challenge to the shoulder complex and muscles that are mainly designed for stability. This changes the tendon metabolism owing to increased energy expenditure in the event of shoulder pain. Research has shown that joint power is vital for energy generation and transfer during wheelchair activities. The study found that there is a significant difference between the energy expenditure during 6MPT in participants with shoulder pain (Group A) when compared to participants without shoulder pain (Group B) as shown in Table 2. The energy expenditure in the participants with shoulder pain appears more probably on account of reduction in the mechanical efficiency of the muscles of the shoulder due to muscle imbalance, weakness or shoulder pathology. This causes the muscles of the shoulder to work more to generate the same amount of force for propulsion leading to an increment in the energy expended. Studies implied a linear relationship between energy expenditure and pain during activity. Excessive and repetitive shoulder motion causes pain and overuse injuries resulting in an increase in the energy expenditure. Hence, the presence of shoulder pain could increase energy expenditure during activity significantly.[22-24]

Table 1: Descriptive analysis of Group A and Group B

	Group A	Group B
Age (years), mean±SD	31.95±10.4	28±5.46
Wheelchair usage (years), mean±SD	6.79±1.06	4.43±3.15
Average number of transfers in the day, mean±SD	6.70±2.29	6.65±1.98
Number of school/work hours per week, mean±SD	16.60±13.04	18.60±11.83
Number of sports/leisure hours per week, mean±SD	2.80±1.64	1.65±0.13
Gender (%)		
Male	17 (85)	17 (85)
Female	3 (15)	3 (15)
Dominance (%)		
Right	14 (70)	19 (95)
Left	6 (30)	1 (5)

SD: Standard deviation

Table 2: Comparison of energy expenditure (physiological cost index) between Group A and Group B using Mann-Whitney U-test

	PCI mean rank	*Z*	*P*
Group A	24.83	−2.342	0.018
Group B	16.18		

PCI: Physiological Cost Index

Conclusion

The Xiaomi MI fitness band proved to be an important tool in monitoring the heart rate. The integration of wearable technology to healthcare can address many challenges posed to rehabilitation. Energy expenditure is significantly higher in individuals with shoulder pain after SCI making it immensely relevant to monitor and prevent shoulder pain during rehabilitation. Health Technology Tools should be promoted for the rehabilitation of patients in this era of modern medicine.

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Conflicts of interest

There are no conflicts of interest.

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