

## Orthopaedic Rehabilitation

# The Physiological Benefits and Problems Associated With Using Standing and Walking Orthoses in Individuals With Spinal Cord Injury—A Meta-analytic Review 脊髓受創的患者在使用站立和走動支架時的生理益處和問題————一個統合分析的回顧

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### ABSTRACT

Spinal cord injury (SCI) patients use two transportation systems that include orthosis and wheelchair. It was claimed that standing and walking bring some benefits for SCI patients, such as decreasing bone osteoporosis, preventing pressure sores, and improving various physiological functions. The main question posted here is as follows: Is there enough evidence to support the effect of walking with orthosis on the health status of the patients with SCI? A review of the relevant literature was carried out in Bioengineering Unit of Strathclyde University. The benefits of orthoses were evaluated. Evidence reported in the literature regarding the effectiveness of orthoses for improving the health condition of SCI patients is conflicting. The benefits that were mentioned in various research studies regarding using the orthosis include decreasing bone osteoporosis, preventing joint deformity, improving bowel and bladder function, improving digestive system function, decreasing muscle spasm, improving independent living, improving respiratory and cardiovascular systems function. Improvement of independence living and physiological health of the patients are the only two benefits that are supported by strong evidence. Unfortunately, conflicting results in the literature have led to criticism of most hypotheses based on theoretical grounds, with the effects of using orthoses on the health status remaining a matter of considerable debate.

### 中文摘要

介紹： 脊髓受創的患者能使用兩種運送系統包括支架和輪椅。有聲稱站立和走動能帶給患者一些益處，如減少骨質疏鬆症，防禦壓瘡及改善多樣生理功能。最重要問題是有沒有足夠的證據支持用支架走路對患者的健康狀況有幫助呢？

方法： 英國格拉斯哥的斯傑克萊大學的生物工程學系做了一個相關文獻的統合分析回顧，對支架的益處作出評估

結果： 文獻證據顯示脊髓受創的患者使用支架助行對改善健康的效用是矛盾的。有些研究提出的益處如減少骨質疏鬆症，防禦關節攣縮，改善腸道和膀胱功能，促進消化系統功能，減少肌肉痙攣，改善獨立生活的能力，並呼吸和心血管功能等。其中只有改善獨立生活的能力和生理健康這兩方面上有強烈證據支持。

結論： 不幸地，這些在文獻上矛盾的結論被批判為基於理論層面而作的假設而已，使用支架對能幫助患者的健康狀況仍然有極大的爭議

## Introduction

Spinal cord injury (SCI) is damage to the spinal cord that results in loss of mobility and sensation below the level of injury. This

disorder is characterised according to the amount of functional loss, sensation loss, and inability to stand and walk.<sup>1–3</sup> The incidence of SCI varies among countries. For example, there are 12.7 and 59 new cases per million in France and the United States of America, respectively.<sup>4,5</sup> It may be a result of trauma (especially motor vehicle accident), penetrating injuries, or diseases. As a result of

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this type of disability, most SCI individuals rely on a wheelchair for their mobility. They can transport themselves from one place to another using a manual wheelchair with the speed and energy expenditure that is similar to normal individuals.<sup>6,7</sup>

The main problems of using wheelchair are the restriction to mobility owing to architectural features in the landscape and a number of health issues because of prolonged sitting. Decubitus ulcers; osteoporosis; and joint deformities, especially hip joint adduction contracture, can result from prolonged wheelchair use.<sup>8</sup> SCI individuals often undergo various rehabilitation programmes for walking and exercises. It is claimed that walking is a good exercise for paraplegics to maintain good health, decrease urinary tract infections, improve cardiovascular and digestive systems functions, and improve psychological health.<sup>8</sup>

In contrast, most patients prefer not to use an orthosis or to use it occasionally. The main problem with orthosis use is the high energy demands it places on the users during ambulation. The walking speed of an SCI patient with an orthosis is significantly less than that of normal walking and also in contrast to mobility with a wheelchair.<sup>9–13</sup>

Donning and doffing of the orthosis is another important problem associated with orthosis usage.<sup>14</sup> The high percentage of the force applied on the upper limb musculature is another issue that affects the use of orthoses. Depending on the style of walking, between 30% and 55% of body weight (BW) is applied on the crutch during walking.<sup>15–17</sup> The high value of the force that is transmitted to the upper limb joints increases the incidence of some diseases and also shoulder pain.<sup>18,19</sup> Fear of fall, especially during performing hand functions, is another problem of using an orthosis.

Although standing with an orthosis may have some benefits for the patients, it has a lot of problems. Hence, the main question posted here is that can walking and standing with an orthosis fulfil the aforementioned benefits or not? Unfortunately, the information given in some text books regarding the benefits of using an orthosis for SCI individuals is based on survey-based studies. Hence, the aim of this review article was to evaluate the available evidences regarding the effect of using orthoses on physiological improvement of patients with SCI. Does walking with orthosis bring some benefits to the patients or not? Moreover, it was aimed to evaluate the performance of the patients and to discuss the problems associated with using orthoses.

## Methods

An electronic search was done through the PubMed, Embase, and ISI Web of Knowledge database from 1960 to 2010 (Figure 1). The abstract and title of each study were assessed by the author. A first selection of relevant article was done based on whether the title or abstract addressed the research questions of interest (based on the keywords, which included Spinal Cord injury, Physiological benefits, Walking, Standing, and Orthosis). The second selection of the articles was done according to the following criteria:

1. Experimental studies published in English;
2. Addressing adults and children with paraplegia or/and quadriplegia;
3. The patients used orthoses or frame to improve some parameters, such as bone mineral density (BMD), respiratory system function, cardiovascular system function, joints' range of motion.

## Results

From an initial list of 100 articles, 40 were fully retrieved and reviewed, based on the included parameters. The results of the

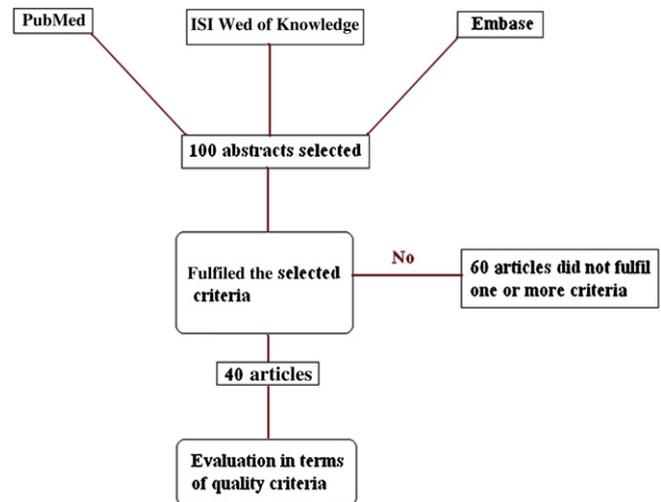


Figure 1. The stages that were selected in this research study.

research articles were fully reviewed and categorised based on the physiological benefits mentioned in the literature. The performance of the patients in walking with orthosis was categorised based on the magnitude of energy consumption during walking (Table 1),<sup>35,37,38</sup> stability while standing, and gait parameters.

## Discussion

### *The effects of using orthosis and standing on BMD*

According to the results of the research conducted by Goemaers et al (1983), BMD of long bone (femur and tibia) decreased significantly after injury. Most of the research done regarding the effects of using orthosis on BMD showed that walking and standing with orthoses do not influence the magnitude of osteoporosis. The preservation of BMD in lumbar spine is more than that in long bones. It may be the result of maintaining the loads on the spine while sitting in a wheelchair.<sup>20–27</sup> There was one research which mentioned specifically that walking with orthosis brought a lot of physiological benefits for the individuals without presenting any evidence.<sup>8</sup>

The other important parameters regarding the effects of standing and walking on BMD is the duration of using an orthosis. It was shown that walking and standing with an orthosis must be done lifelong and must be repeated several times a week to have any effects on bone osteoporosis (at least five times per week and 1 hour for every session). Being ambulatory by using mechanical orthoses and the neurological status (muscles stress) are two important parameters that influence BMD.<sup>20–28</sup> However, the results of various research studies showed that the effect of the latter is more important.

The type of the injury (complete or incomplete) influences the BMD; patients with an incomplete lesion have greater BMD than those with a complete one. Every effort should be taken to prevent an incomplete SCI progressing into a complete one.<sup>24,25</sup> Lastly, some of the research studies have been carried out on spina bifida and myelomeningocele patients, in which the outcome differs from those of SCI resulting from trauma.<sup>31</sup>

### *The effects of skin integrity*

The effects of skin integrity are shown in Table 2.<sup>29–31</sup>

**Table 1**  
The energy consumption of paraplegic patients during walking with various orthoses

Reference no.	No. of patients	Level of lesion	Type of orthosis	Style of walking	Walking velocity	Energy cost (J/kg/m)	Energy consumption (J/kg/min)
37	8	C <sub>7</sub> –T <sub>12</sub>	Scot Craig KAFO with crutch	Swing through gait	17.5	63.95	—
37	8	C <sub>7</sub> –T <sub>12</sub>	KAFO with single-stop ankle joint with crutch	Swing through gait	15.3	73.15	—
37	8	C <sub>7</sub> –T <sub>12</sub>	Scot Craig KAFO with walker	Swing through gait	8.8	26.38	—
37	8	C <sub>7</sub> –T <sub>12</sub>	KAFO with single-stop ankle joint with walker	Swing through gait	6.3	36.78	—
35	4	T <sub>8</sub> –T <sub>12</sub>	WBC	Reciprocal gait	19	119.5	—
38	6	T <sub>4</sub> –T <sub>12</sub>	ARGO	Reciprocal gait	—	—	355.58
38	6	T <sub>4</sub> –T <sub>12</sub>	NRGO	Reciprocal gait	—	—	376.1

ARGO = advanced reciprocating gait orthosis; KAFO = knee ankle foot orthosis; NRGO = advance reciprocal gait orthosis without cable; WBC = weight-bearing control orthosis.

### The effects of standing on spasticity

Most researches are survey based (Appendix, Table 6). There was a favourable response by SCI patients on the effects of using orthosis on spasticity. However, the pitfall of these studies is that the return rate of the questionnaires was rather low.<sup>26,33</sup>

Standing and walking with an orthosis extends the hip and knee joints and stretches the surrounding muscles. Applying BW through the legs reduces muscle spasm more efficiently than stretching the muscles only in a supine position. However, there is no evidence to support it.<sup>8</sup>

### Effects of standing and walking with orthosis on respiratory function

In standing position, the pelvic tends to tilt more anteriorly than in sitting position. This increase lumbar lordosis stabilises a better alignment of the spine in an extended posture. In this posture, the force applied on the internal organs decreases, and as a result, the performance of respiratory organs increases.<sup>8</sup> However, it was shown by Ogilvie et al<sup>32</sup> that orthosis usage and ambulation did not affect the respiratory function of participants 24 months after continued use of an orthosis.

### Improving bowel and bladder functions

There is only one research study based on national survey of a sample of individuals with SCI (paraplegia and quadriplegia). The patients who participated in this research study mentioned that walking with orthosis decreases the number of urinary tract infections and regulates bowel and bladder function.<sup>30</sup>

### Prevention of joint deformity and improving joint range of motion

Other benefits that were mentioned by Douglas et al<sup>8</sup> regarding the usage of orthosis were prevention of joint deformity and

**Table 2**  
The effects of standing and walking on skin integrity

Reference no.	Method	Results
29	152 adults with SCI; age, 34 y. A 17-item self-reporting survey questionnaire was sent to 463 patients	Only 152 returned the questionnaire. They mentioned some benefits that included skin integrity, well-being, and others
30	This was an investigation through a national survey of a sample of individuals with SCI	There was a favourite response by some individuals on the effects of standing devices on the number of bed sores
31	36 spina bifida patients used wheelchair compared with another 36 patients who walked with orthosis	The patients who walked early had fewer fractures and pressure sores, were more independent, and were better able to transfer

ARGO = advanced reciprocating gait orthosis; NRGO = advance reciprocal gait orthosis without cable; SCI = spinal cord injury.

**Table 3**  
The PCI of paraplegic patients during walking with various orthoses

Reference no.	Type of orthosis	PCI (beats/m)
10	HGO	0.95–1.65
10	Parawaker 89	0.8–1.26
38	ARGO	5.4
38	NRGO	5.8
39	Walk about	11.5
39	MMLO	11.5
36	WBC	1.9
36	HGO	3.6

ARGO = advanced reciprocating gait orthosis; HGO = hip-guided orthosis; NRGO = advance reciprocal gait orthosis without cable; PCI = Physiological Cost Index, measured by the difference of walking heart rate and resting heart rate divided by walking speed; MMLO = moorong medial linkage orthosis; WBC = weight-bearing control orthosis.

improvement of joint range of motion. They claimed that during standing, the BW is applied vertically downwards and symmetrically on both feet. In this position, the gravitational positioning of flexed joints decreased, and as a result, the risk of deformity of lower limb joint decreased.<sup>8</sup> Middleton et al<sup>33</sup> were the other researchers who mentioned that maintaining range of motion and preventing joint deformity were the two most important outcomes represented by the participants. However, they did not show any evidences to support their finding.

### Problems associated with using orthoses

According to the results of various research studies, the main problem of orthosis use is the high energy demand it places on the users during ambulation (Table 3).<sup>10,36,38,39</sup> The walking speed of individuals with SCI with an orthosis is significantly less than that of normal walking and also in contrast to mobility with a wheelchair.

The high percentage of the force applied on upper limb musculature is another issue that affects the use of orthosis. Depending on the style of walking, between 30% and 55% of BW is applied on the crutch during walking.<sup>15,34,40,41</sup> The high value of the force that is transmitted to upper limb joints increases the incidence of some diseases and also shoulder pain.

Donning and doffing of orthoses is another important problem associated with orthosis usage. Hawran and Biering<sup>14</sup> found that only 3 of 45 patients continued using their orthosis after 10 years. The reason that they mentioned for withdrawing from the use of orthoses was the considerable amount of time that they needed to spend in putting and taking off the orthosis.<sup>14</sup>

### Conclusion

It was mentioned in the literature that walking with orthosis brings some benefits for individuals with SCI, such as improving

BMD; improving the functions of cardiovascular, digestive, and respiratory systems; decreasing muscles spasm and joint contractions. However, the results of some researches showed that the effects of using orthosis on physiological health are not as many as supposed to be. There is no strong evidence that using orthosis can decrease bone osteoporosis and muscle spasm and improve general health. Moreover, most of the researches in this field are survey based. It can be concluded that the orthosis for standing and walking must be used lifelong to have any influence on the health status of SCI patients. Moreover, they have to use the orthoses four to five times per week for at least 1 hour per session.

A variety of orthoses has been designed to enable SCI individuals to stand and walk again, which use different mechanisms to stabilise the paralysed joints and to move the limbs forward during walking. Different sources of power, such as pneumatic and hydraulic pumps, muscular force resulting from electrical stimulation, and electrical motors, have been attempted for walking. However, the results of different research have shown that the performance of the SCI individuals during walking with the mechanical orthosis is very low, and the patients experience a lot of problems in using the orthoses. Many of the SCI individuals withdraw from using their orthoses after they obtain it. The patients reported some problems, such as walking with orthoses is a demanding task in terms of energy expenditure and the mechanical work required; poor cosmesis of the orthoses, especially the hip-guided orthosis; donning and doffing the orthosis takes considerable time and sometimes they need assistance; and experience problems related to fear of falling.

To gain the benefit of using orthosis in patients with SCI, self-motivation and commitment of long-term use must be strongly held by the patients and the supporting members.

## Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jotr.2011.07.008.

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