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Review

Balance control in lower extremity amputees during quiet standing: A systematic review

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ABSTRACT

Postural control has been widely evaluated for the normal population and different groups over the past 20 years. Numerous studies have investigated postural control in quiet standing posture among amputees. However, a comprehensive analysis is lacking on the possible contributing factors to balance. The present systematic review highlights the current findings on variables that contribute to balance instability for lower extremity amputees.

The search strategy was performed on PubMed, Web of Science, Medline, Scopus, and CINAHL and then followed by additional manual searching via reference lists in the reviewed articles. The quality of the articles was evaluated using a methodological quality assessment tool. This review included and evaluated a total of 23 full-text articles.

Despite the inconsistencies in the methodological design of the studies, all articles scored above the acceptable level in terms of quality. A majority of the studies revealed that lower extremity amputees have increased postural sway in the standing posture. Asymmetry in body weight, which is mainly distributed in the non-amputated leg, was described. Aside from the centre of pressure in postural control, sensory inputs may be a related topic for investigation in view of evidence on their contribution, particularly visual input. Other balance-related factors, such as stump length and patients' confidence level, were also neglected. Further research requires examination on the potential factors that affect postural control as the information of standing postural is still limited.

1. Introduction

Postural balance, which refers to the essential ability of maintaining daily functions and involving in sports activities, has become one of the major concerns among the society. Balance can be defined as the ability to regain the centre of mass (CoM) within the base of support to maintain body equilibrium. The CoM reflects the centre of body location movement and changes accordingly to preserve balance. It also serves as an important factor in lower extremity amputation (LEA) where balance impairment may increases the risk of falling. In 2007, an estimated 1.7 million people were reported to have lost limbs (excluding fingers) in the United States. A trend of increasing hospital costs is associated with amputation incidences.

Several reasons lead to amputation, such as vascular diseases and peripheral arterial diseases. Diabetes patients have 10–30 times greater lifetime risk of undergoing LEA compared with the general population [1]. About 20–50% of diabetes amputees will require second leg amputation within one to three years, and more than 50% of the amputees will need amputation within five years [2]. Due to the missing limb in the lower extremity, the range of displacement is affected, and new movement patterns that require preserving balance are essential. For example, patients with missing ankle and knee joints may need to adopt adjustment strategies to regain stability during locomotion.

Multi-factorial components contribute to postural balance and there might be other contributing factors have not been found. Although balance control strategies in LEA are different from the general population, the contributing elements are similar. Horak [3] suggested that six sub-components are required to retain postural balance, including biomechanical constraints, movement strategies, sensory strategies, orientation in space, control of dynamics, and cognitive processing. The studies of sensory strategies for balance control demonstrated the important role of integrations among visual, vestibular, and proprioception

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elements in quiet standing. Acquisition of motor control through the central nervous system stimulates the reflective output of movement, where the incoming information obtained from the sensory systems is transmitted to the nervous system. Moreover, the presence of ankle strategy that assists in balance recovery generates compensatory torque around the ankle joints during small motions, whereas hip strategy helps in sustaining balance around the hip joints during larger movement.

Static balance control serves as a balance indicator of dynamic control via postural sway. Postural sway can be defined as the deviation in the position of the centre of pressure (CoP) on the supporting surface. As the upright standing posture is a complicated task for amputees, three main aspects are used to measure the human standing posture: (1) body segment displacement, (2) muscle activity, and (3) movement pattern of CoM and CoP [4]. The most frequently measured parameter is CoP sway. Among different methods for assessing CoP, the force plate, which involves measurement of CoP displacement with transducers during standing posture, is commonly used.

Horak [3] reviewed the interaction and contribution among various physiological systems associated with balance. However, earlier findings were only limited for the general population. The present systematic review provides summaries of literature studies on standing balance characteristic in LEA. Furthermore, the review investigates the association between these balance characteristics and balance ability among LEA patients.

2. Methods

2.1. Search strategy

The electronic search of databases performed in May 2013 was limited to PubMed, Web of Science, Medline, Scopus, and CINAHL. The articles were limited from January 1975 to May 2013 (including E-pub ahead of print publication). The key MESH terms included "balance", "amputee", and "standing". A comprehensive search was performed with the combination of the other relevant keyword search terms: "static", "lower limb", "stance", and "control". Additional manual search was supplemented by manual screening conducted for relevant articles based on reference lists of the retrieved articles. The additional search was performed to avoid the possibility of those overlooked articles.

2.2. Eligibility

Only full-text articles in English were selected from the electronic databases. The search strategy was independently performed by two authors (KPX and NAAO). If article disagreement in screening process existed, the article was discussed to reach consensus. The titles and abstracts screening process included articles on studies that focused on the investigation of amputees' balance for static standing posture. Articles that met the following criteria were considered: (1) human participant, (2) focus on amputees, (3) studies on variables of static balance, and (4) peer-reviewed, full scientific-based articles. Articles that focused on static balance's modelling, gait analysis, intervention in gait rehabilitation, and effect of prosthetic design were excluded, as well as published reports in conference proceedings. No restriction was applied regarding the sex, age, and year since amputation of the participants.

2.3. Review process

Duplicate articles from different databases were removed. The title and abstract for the selected articles were first screened according to the eligibility criteria. Further full-text evaluation was performed if the title and abstract could not provide adequate information for the article screening process. Rejected articles were re-screened to avoid misinterpretation.

2.4. Assessment of methodological quality

A standardized methodological quality assessment tool does not exist in the field that investigates the risk factor of human balance. Systematic methodological quality assessment method was used to evaluate the quality of retrieved articles and minimize reviewer's bias. Peters et al. [5] utilized 20 appraisal questions as quality indicator to assess 20 reviewed articles. The appraisal questions that they developed was around the major research aims such as objective, study design, subjects' characteristic, sample size, equipment design, movement task, statistical analysis method, key findings, limitation and conclusion.

The evaluation in current review was based on the modification of previous established appraisal criteria [5]. The reviewers specifically assessed the retrieved articles with appraisal questions that were modified based on the main aims of this review, which related to biomechanical evaluation in static balance (see Table 1). The overall score provided a measure in standardized quality indicator and enabled the comparison of research quality among articles. Other considerations were addressed for the full understanding of items that were not described clearly.

3. Results

3.1. Literature search yield

Initially, the electronic database screening process yielded 135 articles. The title and abstract screening process eliminated 91 articles, and agreement was reached for 44 articles, which were identified to be related with the aim of the literature study. Following the eligibility criterion of full-text, 18 articles were selected for review. Five articles were retrieved from the reference lists, yielding a total of 23 articles for the review process (Fig. 1). The most common reason of the articles elimination from analysis was the use of an intervention in gait rehabilitation.

3.2. Quality of reviewed articles

The methodological quality scores for 23 reviewed studies are presented in Table 2. Most of the studies provided complete information on the objective, study design, study interest, main outcomes, and conclusion. A total of 12 articles provided study limitations. The quality assessment scores ranged from 57% to 86% and 16 studies satisfied at least 70% to 90% of the questions [6–21].

Table 1
Methodological quality assessment used in this systematic review.

Question
1. Is the objective of the study clearly described?
2. Is the study design clearly described?
3. Are the subjects' characteristics and details clearly provided?
4. Is the practice trial in the study clearly stated?
5. Is the study randomized to the study group clearly stated?
6. Is this double blind study?
7. Is the distance of foot placement between legs clearly described?
8. Is equipment design and set up clearly described?
9. Are the movement tasks clearly defined?
10. Are appropriate statistical methods used in data analysis clearly defined?
11. Is the actual probability value reported for main outcome clearly stated?
12. Are the main outcomes measure clearly stated?
13. Are the limitations of the study clearly stated?
14. Are the conclusion drawn from the study clearly stated?