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Postural changes after sustained neck muscle contraction in persons with a lower leg amputation

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Abstract

Lower leg amputation generally induces asymmetrical weight-bearing, even after rehabilitation treatment is completed. This is detrimental to the amputees' long term quality of life. In particular, increasing strains on joint surfaces that receive additional weight load causes back and leg pain, premature wear and tear and arthritis. This pilot study was designed to determine whether subjects with lower leg amputation experience postural post-effects after muscle contraction, a phenomenon already observed in healthy subjects, and whether this could improve the weight-bearing on their prosthesis.

Fifteen subjects with a unilateral lower leg amputation and 17 control subjects volunteered to participate in this study. Centre of pressure (CP) position was recorded during standing posture, under eyes closed and open conditions. Recordings were carried out before the subjects performed a 30-s voluntary isometric lateral neck muscle contraction, and again 1 and 4 min after the contraction.

Postural post-effects characterized by CP shift, occurred in the medio-lateral plane in the majority of the amputated (7/15 eyes closed, 9/15 eyes open) and control (9/17 eyes closed, 11/17 eyes open) subjects after the contraction. Half of these subjects had a CP shift towards the side of the contraction and the other half towards the opposite side. In four amputated subjects tested 3 months apart, shift direction remained constant. These postural changes occurred without increase in CP velocity.

Thus, a 30-s voluntary isometric contraction can change the standing posture of persons with lower leg amputation. The post-effects might result from the adaptation of the postural frame of reference to the proprioceptive messages associated with the isometric contraction.

Keywords: Lower leg amputation; Postural asymmetry; Isometric contraction; Post-effects; Proprioception; Vision

1. Introduction

Training for symmetrical weight-bearing is an important issue in the rehabilitation of persons with unilateral lower limb amputation. It is motivated by frequent clinical observations of an asymmetrical weight-bearing in addition to laboratory measures confirming that more weight is taken on the non-amputated leg (Fernie and Holliday, 1978; Geurts et al., 1992; Hermodsson et al., 1994; Isakov et al., 1992). Altered force platform centre of pressure (CP) measures have also been demonstrated in persons with lower leg amputation. Increased anterior–posterior and medio-lateral CP oscillations have been shown (Fernie and Holliday, 1978; Geurts et al., 1992; Hermodsson et al., 1994; Isakov et al., 1992) while others reported decreased oscillations (Gauthier-Gagnon et al., 1986; Vittas et al., 1986).

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Beside affecting walking performance, the postural changes, and particularly the increased load on the non-amputated leg, are thought to cause additional blood flow deficits in persons with vascular disease (Gauthier-Gagnon et al., 1986), back and leg pain (Hagberg and Branemark, 2001) and premature wear and tear and arthritis on a long term basis because of the increased ground reaction forces (Nadollek et al., 2002). Thus, asymmetrical weight-bearing could impair functional capacities (Jones et al., 2001), thereby further reducing the quality of life of persons with lower leg amputation. Moreover, the postural asymmetry was shown to be difficult to correct through either classical rehabilitation (Geurts et al., 1992; Isakov et al., 1992), or training using augmented sensory feedback of limb load pressure (Gauthier-Gagnon et al., 1986).

A procedure able to alter standing posture by means of a 30-s neck muscle isometric contraction with head straight has recently been described in able-bodied people (Duclos et al., 2004). It is based on the well-known "Kohnstamm phenomenon" where an involuntary movement occurs after a sustained isometric muscle contraction (Kohnstamm, 1915). The contraction, which was exerted in a sitting position, induced an involuntary, oriented and prolonged body leaning when the subjects stood up and closed their eyes after the end of the contraction. As an example, 11 of the 14 tested subjects were leaning leftward after 30 s of isometric effort towards the left side. Moreover, this "postural post-effect" persisted and remained oriented in this same direction for an average of 8 min after the end of contraction. Authors suggested that the post-effect is a consequence of a change in postural reference induced by the prolonged and strong proprioceptive message associated with the isometric voluntary contraction. Interestingly, this post-contraction postural effect was quite comparable to that described after muscle vibration (Duclos et al., 2005, 2007; Gilhodes et al., 1992; Wierzbicka et al., 1998). Such a postural change could eventually help amputees to increase weight-bearing on their prosthetic side.

In order to test whether a postural post-effect could be induced in persons with an amputation, we assessed the effects of a 30-s neck muscle isometric contraction on these persons' standing posture in eyes closed and open conditions and we compared them with those of non-amputated control subjects. The hypothesis of this study was that post-effects can alter standing posture in some lower leg amputees to help them place more weight on their prosthesis. Thus, the objectives of this pilot study were: (1) to confirm medio-lateral postural changes in persons with lower limb amputation by studying centre of pressure displacements, (2) to investigate the proportion of these persons that can show oriented postural post-effects following a maneuver as simple as a voluntary isometric neck muscle contraction, and (3) to document the impact of this maneuver on weight-bearing with and without vision in the subjects who experienced post-effects in the two groups. The results encourage future studies to evaluate postural post-effects training as a tool in the rehabilitation process.

2. Methods

2.1. Subjects

Fifteen subjects (42 ± 10 years old) with lower limb amputation (Table 1) were selected according to the following inclusion criteria: less than 60 years old, unilateral amputation due to trauma or cancer, more than 6 months of prosthetic training, and painless weight-bearing on the prosthesis. Subjects were excluded if the amputation was of vascular origin and if the Berg Balance Scale score (see below) was less than 50/56. The levels of amputation were trans-tibial ($N = 10$), trans-femoral ($N = 4$) and through knee ($N = 1$). Six subjects were amputated on the right leg, nine on the left leg. The mean average time since amputation was 5 years 4 months (median: 4 years; range: from 8 months to 21 years) before the study. Seventeen non-amputated healthy individuals of the same age (38 ± 10 years old, $p = 0.21$) participated as control subjects. This study was approved by the institutional ethics committee and informed consent to the experimental procedure was obtained for all participants.

2.2. Clinical evaluations

Each subject's balance was clinically assessed by means of the Berg Balance Scale (Berg et al., 1992, 1995). A score equal or above 50/56 was required to have subjects with balance skills sufficient for the needs of the postural experimental tasks. Amputated participants experienced most of the difficulties in tandem standing (six did not reach the maximal score) and forward reaching (five did not reach the maximal score). The Berg Balance Scale scores are presented in Table 1. The mean score of the amputees group (55 ± 1, mean $\pm$ SD) confirmed the good balance ability level of the amputees group. No exclusion occurred because of this test. The control group obtained a mean of 55.9/56 (one subject did not obtain the maximal score on forward reaching). Subjects with an amputation were also asked to fill in the Prosthetic Profile of Amputees (Grise et al., 1993) for information on their level of activity and use of their prosthesis. All the amputees could put on their prosthesis without aid, walk on all surfaces (two needed supervision), wear their prosthesis more than 8 h a day (median: 14 h; range: 8–16 h) and all but one (femoral amputee, 6 months since the beginning of prosthetic training) were involved in physical activity (i.e. walking, golf, skating, hiking, etc.) more than 4 h per week.

2.3. Equipment

The Balance Master (NeuroCom® International, Clackamas, USA) was used as a force platform to record centre of pressure (CP) displacements during the postural tests. Subjects were free to move, yet they were secured by means of a parachute-like harness that prevented them from falling to the ground but was not used to support their weight. A manual dynamometer (Lafayette® Manual Muscle Test System, Lafayette, USA; equipped with a Wheatstone bridge strain gauge load cell) was used to measure the maximal isometric force exerted during lateral head and trunk efforts (see Section 2.5).

2.4. Postural test

Subjects were asked to "stand quietly, and as relaxed as possible", on the platform in order to oscillate as naturally and freely