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Review

Trunk involvement in performing upper extremity activities while seated in neurological patients with a flaccid trunk – A review

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ABSTRACT

Background: Trunk control is essential during seated activities. The trunk interacts with the upper extremities (UE) and head by being part of a kinematic chain and by providing a stable basis. When trunk control becomes impaired, it may have consequences for the execution of UE tasks.

Aim: To review trunk involvement in body movement and stability when performing seated activities and its relation with UE and head movements in neurological patients with a flaccid trunk, with a focus on childhood and development with age.

Methods and procedures: A search using PubMed was conducted and 32 out of 188 potentially eligible articles were included.

Outcomes and results: Patients with a flaccid trunk (e.g. with spinal cord injury or cerebral palsy) tend to involve the trunk earlier while reaching than healthy persons. Different balance strategies are observed in different types of patients, like using the contralateral arm as counterweight, eliminating degrees of freedom, or reducing movement speed.

Conclusions and implications: The key role of the trunk in performing activities should be kept in mind when developing interventions to improve seated task performance in neurological patients with a flaccid trunk.

1. Introduction

Control of upper body movement is essential when performing daily activities in a seated position. Trunk control is indispensable during seated activities, because it interacts with control of the upper extremities (UE) and the head by being part of a kinematic chain and by providing a stable base. In the kinematic chain of UE movement, trunk movement enlarges the workspace [1], but trunk displacement is also observed when reaching within arm length [2]. Voluntary UE movement will disturb posture, which is compensated for by postural adjustments to maintain stability [3]. The trunk is involved in this postural chain when performing UE movements. Therefore, in terms of stability, trunk control greatly determines the precision of UE movement [4]. With regard to head movement, trunk movement enlarges the range of head motion in space. Lastly, trunk stability is essential for head balance as well as for accurate visual and vestibular control of posture and voluntary movements of (parts of) the body, such as the arm and hand [5,6].

Trunk control is impaired in patients with a flaccid trunk, affecting their performance of daily activities. In addition, during their development, children with a flaccid trunk have a higher risk in developing scoliosis, which further complicates the interaction between the trunk and UE. A flaccid trunk is typically associated with (severe) muscle weakness due to primary muscle disease (e.g. Duchenne muscular dystrophy (DMD)) or motor neuron disease (e.g. spinal muscular atrophy (SMA)), but it may also be present in patients with central neurological disease with bilateral paresis [7,8]. For instance, patients with 'high' spinal cord injury (SCI) (above thoracic level 6) may have spastic muscles below lesion level, particularly in their extremities, but often their trunk muscles lack normal (reticulospinal and vestibulospinal) control of postural tone mediated by the brainstem via the medially descending spinal tracts [9,10]. As a result, these patients lack automatic trunk control which, in complete spinal cord lesions, cannot be compensated by the medial corticospinal descending neurons. Likewise, patients with severe (mostly bilateral) cerebral palsy (CP) may suffer from lack of postural tone as well as voluntary control of trunk muscles through lesions of their medially descending corticospinal and bulbospinal tracts [11].

When trunk control becomes impaired early in life, it may severely affect motor development in general and, through delayed and limited motor skills, even affect the cognitive and emotional development in children. Because many of the conditions mentioned above may

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become symptomatic during (early) childhood and because a substantial proportion of these children will not be able to walk once they have reached adulthood, studying the consequences of trunk impairments for the performance of seated UE activities is of utmost important. Undoubtedly, the interaction of the trunk with the UEs and the head will depend on the type and the stage or severity of the disease. In children with CP, the UEs are often spastic, ataxic or dyskinetic, whereas in DMD and SMA muscle weakness is most prominent, which may result in differently disturbed interactions with a flaccid trunk. SCI most often occurs in adults, but it may also be present in childhood due to e.g. trauma, neoplasma or infection. Depending on the lesion level, a flaccid trunk may coincide with normal UE function (high thoracic lesions) or impaired UE function (cervical lesions). Therefore, the interaction between trunk, UE and head movements may differ between diagnoses. The impact of a flaccid trunk is probably also dependent on age. First, the interaction between trunk, UEs and head changes with age due to maturation [12,13]. Second, children are more prone than adults to develop spine deformities due to muscle weakness, which also affects their trunk movement and stability [14].

The goal of this review was to provide an overview of the changes in trunk movement and stability when performing UE activities in a seated position, and their relation with UE and head movements in neurological patients with a flaccid trunk compared to healthy subjects. A special focus will be given on childhood and development with age.

2. Methods

PubMed was used as an electronic database to search for studies up to September 2016. Four search term categories were used in the search strategy: (1) population, (2) tasks, (3) body segments, and (4) outcomes (i.e. kinematics or stability). The key terms for each category were:

1. “muscular dystrophies”, “spinal muscular atrophy”, “Duchenne”, “cerebral palsy”, “spinal cord injuries”, “ spinal dysraphism”, “spina bifida” or “healthy”
2. “reach”, “reaching”, “drinking”, “activities of daily living”, “ADL”, “daily activity” or “pointing”
3. “upper body” or “arm” combined with either “trunk”, “torso” or “head”, “upper extremity” combined with either “trunk”, “torso” or “head” or “trunk” combined with “head”
4. A. Kinematics: “movement”, “motion”, “kinematics”, “motor skills” or “coordination”

   B. Stability: “postural balance”, “balance”, “stability”, “postural control”, “sway” or “postural adjustments”

The literature search was performed according to the PRISMA guidelines [15]. Studies were included when written in English. The articles were sorted in two phases. First, articles were screened by title and were included if the topic was potentially relevant. Studies related to standing activities, gait, or therapy evaluations were excluded. Subsequently, the abstracts were read by the primary researcher (LP) and full articles were included when they met the following criteria: 1) covering the topic of task performance in a seated position, 2) involving both trunk and arm or head movement, and 3) presenting outcome measures related to kinematics (range of motion in three planes, movement trajectory, and/or spatiotemporal parameters such as movement velocity and timing of movement) or stability (center-of-mass/center-of-pressure displacement, trunk sway parameters, and/or force profiles). Relevant cited, yet unidentified, articles that met the inclusion criteria were included in second instance.

3. Results

3.1. Search results

The literature search and article inclusion are shown in Fig. 1. Out of 188 potentially eligible articles, 32 articles were eventually included in this review. The study characteristics are shown in Table 1.

The populations addressed in the selected articles consisted of patients with CP or SCI, and/or healthy participants. No studies were found involving patients with neuromuscular disorders or spinal dysraphism/spina bifida. 3D-optical motion tracking was most frequently used for kinematic analysis and force plates for analysis of postural stability. Reaching and reach-and-grasp tasks were most often studied in either an supported or unsupported sitting position. Relatively few studies dealt with point tasks or ADL.

3.2. Interaction trunk – arm

Target distance and object weight have been identified as determinants of trunk involvement during reaching in healthy adults [16]. The trunk is already involved in movement when reaching at approximately 90% of arm length distance [2,17,18] and when performing daily tasks within arm length [19]. Healthy children up to the age of 10 years, used their trunk significantly more compared to adults when reaching forward within arm length and also showed more variability [12,20]. Children with CP showed even more trunk movement and decreased elbow extension when performing various arm tasks compared to healthy children [20–29]. Increased trunk movement is regarded as a compensatory strategy for impaired elbow extension and supination, particularly when reaching in the sagittal plane. Even when reaching forward with the least affected side, increased trunk flexion has been reported in children with CP, albeit non-significant [28]. In addition, increased trunk rotation has been described by Kreulen, Smeulders [24] when performing a drinking task.

With greater target distance, trunk movement increased in all planes in healthy children, but only trunk flexion increased in children with CP [28]. Increased trunk flexion was associated with more elbow extension in healthy children, whereas it was associated with less elbow extension in children with CP [28]. Besides differences in trunk movement, the movement of the reaching arm was slower and less straight, and peak velocity was lower in children with CP compared to healthy subjects [26,30].

Postural stability has been shown to be influenced by task demands in healthy subjects [4,18,31]. Increased stability was seen when a large degree of precision was required (e.g. tracing task) and decreased stability when performing UE movements which perturb posture more (e.g. aiming task) [4]. Children with CP showed postural imbalance while sitting as indicated by decreased maximum reaching distances and/or reaching performance [30,32,33], increased body sway [34], or a decreased Trunk Control Measurement Score [35]. Postural stability was found to be worse during task performance compared to quiet sitting in children with CP [20,35]. However, worse postural control did not always influence the accuracy of task performance during throwing, as shown by Huang, Pan [32]. Postural stability was worse when reaching laterally compared to reaching forward in children with CP [30,34,35]. Saavedra, Joshi [26] and Santamaria, Rachwani [29] studied the influence of external support on trunk stability and arm function. Adding external trunk support improved reaching performance and posture. The adequate level of support was dependent on disease severity; patients with Gross Motor Function Classification Scale (GMFCS) levels I or II already benefitted from pelvis support, whereas patients with GMFCS level V needed support at axillary level [36]. Importantly, adverse effects on reaching performance and posture were seen when the level of support was higher than the trunk level at which postural deficiencies were observed [29]. Differences in postural stability between different types of CP were also found by Heyrman, Desloovere [35]. Children with bilateral CP of the lower extremities were less impaired in terms of trunk stability, compared to those with bilateral CP of the lower and upper extremities. Children with bilateral CP of the lower extremities had only minor problems of static sitting balance, whereas children with bilateral CP of the lower and upper extremities had significantly impaired postural control while sitting. Children with bilateral CP of the lower limbs had more difficulties when