

Joint stabilising response to lateral and medial tilts

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Abstract

Background. Joint stabilisation processes have been mainly studied comparing groups or joints with different stabilities and mainly focusing on one single parameter. The inherent limitations are discussed and a study, where kinematic, kinetic and electromyographic parameters gained from sudden tilt tests were measured, is presented.

Methods. The response of 24 subjects to sudden lateral and medial tilts of the foot during one legged stance were compared. A three-dimensional foot model was utilised to describe ankle and foot motion. Electromyographic signals of six muscles of the lower limb as well as the horizontal ground reaction forces were analysed.

Findings. Forefoot to rearfoot motion was faster and greater than ankle motion. In general medial tilts showed lower motion amplitudes and angular velocities than lateral tilts but higher horizontal ground reaction force integrals. The electromyography patterns were similar for both conditions. However, a specificity of the muscular response could be identified in the electromyography amplitudes.

Interpretation. The higher mediolateral ground reaction forces, together with the reduced kinematic and no general increase in muscular activation in medial tilts suggest, that passive structures seem to be able to counteract destabilising forces and thus reduce the otherwise needed muscular activation.

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1. Introduction

Functional joint stabilisation, despite being a relatively old issue and having been studied by numerous authors, is not yet well understood. Freeman et al. (1965) stated that “functional instability is usually in first place due to incoordination consequent to differentiation”. Kleinrensink et al. (1994) started his discussion indicating that “since Cohen and Cohen (1956) proposed the ‘arthrokinetik reflex’ as a joint stabilising mechanism, several authors accepted ankle stability to be dependent on an intact reflex mechanism”. Both theses promoted the idea of joint stability relying on propri-

ception and motivated most of the subsequent studies in this field.

One typical approach for studying joint stability is to experimentally induce perturbations and observe the stabilising response. In this context, tilt platform tests have been widely utilised and many results regarding muscle onset latencies are available from the literature (Vaes et al., 2001). This is because it has often been assumed, that shorter electromyography (EMG) onset times correspond to a better proprioception and that proprioceptive deficits as determined by delayed onset times would be one of the factors causing joint instability (Konradsen and Ravn, 1990; Löfvenberg et al., 1995). Despite of controversial results, it seems to be generally accepted that there is a link between functional joint instability and prolonged latency times (Konradsen and Ravn, 1990; Löfvenberg et al., 1995). This is further

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supported by experimental evidences of lowered nerve conduction velocities on stretched nerves or after inversion trauma (Kleinrensink et al., 1994). However there are also several studies that failed to establish the link between latency times and functional joint instability (Isakov et al., 1986; Johnson and Johnson, 1993; Ebig et al., 1997). There are evidences disfavoured the idea of proprioceptive deficits as a primary cause of instability and some studies argue in favour of a main role of central motor programs (Gauffin et al., 1988). Some authors suggested that the main function of reflexes is the updating of motor programs rather than the maintenance of posture in acute situations (Hayes, 1982; Nielsen, 2004).

In a recent review on neural control of movement Nielsen (2004) claims for the need to combine the neurophysiological and the biomechanic/kinematic research traditions to progress in our understanding of motor control. Both traditions have dealt with joint stabilisation. As an example, Bonasera and Nichols (1996) studied the reflex organisation of ankle stabilizers and plantarflexors in decerebrate cats. This study provided experimental evidence on various inhibitory and excitatory neural pathways connecting several muscles around the cat's ankle. However, these highly controlled experiments are done in a very artificial context and it remains open to which extent their results can apply to natural motion. Some other studies done on humans have utilised indirect approaches to examine functional neuronal pathways or interneuronal relationships (see Nielsen, 2004). Most studies pertaining to the biomechanic/kinematic tradition have tried to gain insight into joint stabilisation by means of comparisons between sound and affected joints (Karlsson et al., 1992; Vaes et al., 2001) or populations of stable and unstable subjects (Isakov et al., 1986; Konradsen and Ravn, 1990). Both approaches have major drawbacks: The multifactorial nature of functional joint instability makes it difficult to find groups sharing the same aetiology. Thus, even if a factor is identified for a specific group, this would not mean that it should be present in other cases of functional joint instability. Furthermore, there is evidence of injury or training to one side to effect the contralateral one (Gauffin et al., 1988; Kleinrensink et al., 1994). Another deficiency of the biomechanical studies dealing with joint stabilisation, especially of the foot and ankle complex, is that the kinematics have been widely disregarded and only very simple models have been utilised. From a former study (Arampatzis et al., 2003) we learned that we can not predict the behaviour of the whole ankle and foot complex by observing only one joint. Furthermore the motion of the midfoot joints exceeded the motion of the ankle joint, providing a greater potential to adapt to the ground.

Moreover most studies on ankle stability using tilt plates examined only sudden inversions. So the observed

muscular response has been attributed to the induced inversion. The exclusive observation of lateral tilts does not allow to verify if the observed response is really triggered by the inversion or by other factors common to every joint position perturbation.

From all these, it becomes evident, that there is still need of more research and that the link between the neural part of the sensorimotor system and the mechanical stabilisation process still needs to be enlightened. In the present study rather than identifying factors related to functional instability, it is tried to provide knowledge regarding the stabilisation process itself. So the aim of this study was to examine the influence of two different stabilising demands (lateral and medial tilts) on several related kinematic, kinetic and electromyographic parameters, in order to describe the stabilisation process. We hypothesised that the main adaptation of the foot to the moving plate happens at the midfoot joints rather than at the ankle joint, and that the muscular stabilising response is not necessarily triggered by simple stretch reflexes.

2. Methods

Twenty four subjects, 12 male and 12 female, all active in sports from recreational to competitive level, participated in this study: Weight: 70.6 (SD 10.3) kg, height: 177 (SD 6) cm. All subjects gave their informed consent, and the experimental protocol was approved by the intern ethical committee. The bare left foot was full weight bearing and freely resting on a tilt plate. The longitudinal axis of the foot (posterior midpoint of the calcaneus to second metatarsal head) was placed parallel to the axis of rotation of the plate at a distance of 6.5 cm. The plate axis and hence the foot was in 15° abduction. All subjects underwent lateral and medial sudden unexpected tilts (20°) during one-legged stance. All trials for one tilt direction were consecutive. After at least three successful trials were recorded, the other tilt direction was tested. This was done in random order. The subjects were instructed to bear their whole weight on their left leg, look forwards to a spot on the wall and stand as quiet as possible. The tip of the free leg was allowed to touch the ground to help maintaining balance and reduce EMG activity prior to tilt.

A highly linear potentiometer (10 k Ω , linearity $\pm 1\%$, Megatron, Munich, Germany) was aligned with the axis of the plate and provided data describing the plate rotation at a rate of 1000 Hz. Two dampers reduced the impact caused by the plate stop (last 5°). A force plate (Kistler, type: 9881B21, Winterthur, Switzerland) operating at 1000 Hz was situated under the tilt plate. Tilt onset was determined as the instant at which the vertical ground reaction forces (GRF) fell below 90% of its mean value prior to tilt. Foot motion was captured by

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