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Altered knee joint neuromuscular control during landing from a jump in 10–15 year old children with Generalised Joint Hypermobility. A substudy of the CHAMPS-study Denmark

Tina Junge [a,b,c,*], Niels Wedderkopp [a,d], Jonas Bloch Thorlund [e], Karen Søgaard [e], Birgit Juul-Kristensen [e,f]

[a] Institute of Regional Health Services, University of Southern Denmark, Odense, Denmark
[b] Department of Physiotherapy, University College Lillebaelt, Odense, Denmark
[c] Health Sciences Research Centre, University College Lillebaelt, Odense, Denmark
[d] Spine Centre of Southern Denmark, Hospital Lillebaelt, Middelfart, Denmark
[e] Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark
[f] Institute of Occupational Therapy, Physiotherapy and Radiography, Bergen University College, Bergen, Norway

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ABSTRACT

Generalised Joint Hypermobility (GJH) is considered an intrinsic risk factor for knee injuries. Knee neuromuscular control during landing may be altered in GJH due to reduced passive stability. The aim was to identify differences in knee neuromuscular control during landing of the Single-Leg-Hop-for-Distance test (SLHD) in 25 children with GJH compared to 29 children without GJH (controls), all 10–15 years. Inclusion criteria for GJH: Beighton score $\geqslant 5/9$ and minimum one hypermobile knee. EMG was recorded from the quadriceps, the hamstring and the calf muscles, presented relative to Maximum Voluntary Electrical activity (MVE).

There was no difference in jump length between groups. Before landing, GJH had 33% lower Semitendinosus, but 32% higher Gastrocnemius Medialis activity and 39% higher co contraction of the lateral knee muscles, than controls. After landing, GJH had 36% lower Semitendinosus activity than controls, all significant findings.

Although the groups performed equally in SLHD, GJH had a Gastrocnemius Medialis dominated neuromuscular strategy before landing, plausibly caused by reduced Semitendinosus activity. Reduced Semitendinosus activity was seen in GJH after landing, but with no compensatory Gastrocnemius Medialis activity. Reduced pre and post-activation of the Semitendinosus may present a risk factor for traumatic knee injuries as ACL ruptures in GJH with knee hypermobility.

1. Introduction

Biomechanical factors such as knee joint laxity is considered an intrinsic risk factor for traumatic knee joint injuries, e.g. Anterior Cruciate Ligament (ACL) ruptures (Uhorchak et al., 2003; Myer et al., 2008). Individuals with Generalised Joint Hypermobility (GJH) frequently experience knee joint hypermobility or laxity, which is presumed to be an intrinsic risk factor for ACL and other knee injuries in both adults and adolescents (Ostenberg and Roos, 2000; Uhorchak et al., 2003; Ramesh et al., 2005; Myer et al., 2008; Pacey et al., 2010). However, the contribution of GJH and specifically knee joint hypermobility, to the mechanisms behind knee joint injuries is unknown, partly due to a lack of mechanistic studies and inconsistencies in diagnostic tests and criteria for GJH.

GJH is a hereditary condition, which is characterised by increased range of motion due to increased laxity of the connective tissues compared with the normal population. This results in decreased stiffness and stability of the passive structures like joint capsules and ligaments (Grahame, 1999). From a functional perspective, one possible compensation strategy for reduced passive knee joint stability may be increased muscle activation to increase the active stability of the knee joint (Shultz et al., 2004; Hewett et al., 2005). However, it is currently unknown whether a compensation strategy is present during challenging tasks demanding dynamic knee stability, like landing from a jump.

Pre-activation of the stabilizing muscles may increase the dynamic stability of the lower extremity during impact in

* Corresponding author at: IRS, SDU, Winsløwparken 19.3, 5000 Odense C, Denmark. Tel.: +45 30 22 36 32.

E-mail address: tjunge@health.sdu.dk (T. Junge).

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challenging tasks (Rozzi et al., 1999; Hewett et al., 2005). Thus, adequate knee joint neuromuscular coordination and control become crucial, since ineffective muscle recruitment may result in knee positioning with increased ACL strain, thereby increasing the risk of injury (Rozzi et al., 1999; Hewett et al., 2005).

Only few studies of muscle activity in individuals with GJH have been performed (Greenwood et al., 2011a,b; Jensen et al., 2013; Smith et al., 2013). One study of children (10-year old) with GJH and at least one hypermobile knee found neuromuscular coordination and control strategies to differ from controls. This was seen during a submaximal isometric knee flexion task, where hamstring muscle activity was reduced. During the same task, knee muscle co-activation ratio was increased, which was suggested to be a compensatory strategy for the lower hamstrings activity (Jensen et al., 2013). Furthermore, decreased maximum isokinetic knee extension and flexion strength were seen in 10-year old girls and women with GJH and also, decreased knee strength balance (Hamstring/Quadriceps ratio) was seen in adults with GJH (Juul-Kristensen et al., 2012). However, these results were all obtained sitting in an isokinetic dynamometer or in tasks requiring static knee stability. While standing still, adults with GJH and hypermobile knee joints performed equally as well as controls, but had increased knee muscle co-contraction (Greenwood et al., 2011a,b). A selective activation of medial knee muscles, including the medial Gastrocnemius, was seen during challenging tasks for the knee (Besier et al., 2001), while an isolation of the effect of the lateral and the medial muscles of the muscles crossing the knee may reveal which strategies that counters the external loads applied to the joint.

Little is known about potential neuromuscular differences or compensatory strategies in individuals with GJH during dynamic performance tests like the Single-Leg-Hop-for-Distance test (SLHD), simulating components of high load sports or play situations. In order to understand the underlying intrinsic mechanisms of knee injuries in this group, and hence target preventive interventions, knee joint neuromuscular control should be investigated during dynamic loading conditions.

The objective of this study was to identify differences in knee joint neuromuscular control, defined as muscle activity, time of onset and co-contraction, in children with GJH compared with children without GJH (controls) before and after landing from the SLHD test. The hypothesis was that children with GJH present with altered knee joint neuromuscular control with respect to controls during the challenging SLHD test, seen as lower/higher muscle activation, delayed or early time of onset and lower/higher co-contraction.

2. Methods

2.1. Design

This exploratory study was nested in The Childhood Health, Activity and Motor Performance School Study Denmark (the CHAMPS-study DK), a longitudinal cohort study launched in 2008 that follows children from public schools in the Municipality of Svendborg, Denmark (Wedderkopp et al., 2012). The overall aim of the CHAMPS-study is to evaluate the general health of 1300 children (aged 10–15 years), including children with GJH.

2.2. Participants

The children were selected from the CHAMPS-study and contacted individually via their parents to participate in the current study. The status of GJH or control was determined using the Beighton Tests (BT) (Beighton et al., 1973), the results having been obtained from the entire cohort along with other tests one month prior to the current study. In total, 56 children were recruited, 26 with GJH and 30 controls, matched by age and sex at a group level.

Inclusion criteria for children with GJH were a BT score (Junge et al., 2013) of $\geqslant 5/9$, at least one hypermobile knee, and positive standing knee hyperextension confirmed by using a goniometer during supine lying (Ramesh et al., 2005; Myer et al., 2008). Inclusion criteria for controls were a BT score of no higher than 1/9 and no hypermobile knee.

Exclusion criteria for both groups were current pain in the back or lower extremities affecting the ability to jump, previous or current knee trauma, hereditary diseases like Ehlers-Danlos Syndrome, Marfan Syndrome, Osteogenesis Imperfecta and body mass index > 25. Information about previous injuries was obtained from the CHAMPS-study (Wedderkopp et al., 2012).

The Regional Scientific Ethics Committee for Southern Denmark approved the experimental protocol (jnr. S-20080047 HJD/csf) and the study was reported to the Danish Data Protection Agency. Written and oral information about participation in the study was provided to the parents or guardians of the participating child according to the Declaration of Helsinki. Written informed consent for participation was received, and on the day of testing, each child verbally confirmed participation.

2.3. Outcome measures

A standardised test protocol was strictly followed for each child. All testers, except the lead tester, were unaware of each child's status of GJH or control during the study. The lead tester decided the test leg of the child, defined as the leg with the most hypermobile knee joint for the children with GJH, while the test leg for the controls was selected at random. A 10-min standardised warm-up was completed for each child before the SLHD test.

2.3.1. SLHD test

The SLHD test was modified slightly from the original version describing the arms to be held behind the back (Tegner et al., 1986). The child was asked to jump on the test leg as far as possible allowing arm swing assistance and to land standing steadily on the test leg for at least 2–3 s. The child had one practice trial and then three SLHD tests and additional jumps, until no further progress in jump length was observed. Between each test the child had a 30 s rest. The longest jump, measured in cm from the toe in the starting position to the backside of the heel in the landing position, was used for analysis. In a pilot study, reproducibility for SLHD for children aged 11 and 14 years had ICC values for inter-session of 0.93 respectively 0.84 (unpublished data).

2.3.2. Sport participation

The weekly amount of organised sports activity was registered by SMS surveys every week. The SMS question to the parents of the single child was: "How many times did your child participate in organised sports within the last week?" with the possibility to type the relevant number between 0 and 8, with 8 meaning more than 7 times. The individual child's mean amount of organised sports activity during two months was used for analysis.

2.3.3. Maximum voluntary contraction

Maximum voluntary contraction (MVC) for knee flexion and extension was performed during sitting with a straight back without support, the hips at 90° flexion, the knees at 60° flexion and both arms placed across the chest (Thorborg et al., 2013). The moment arm for knee flexion and extension was measured as the distance between the centre of rotation of the knee joint and a line projected perpendicular to the direction of force applied just proximal to the lateral malleolus.