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Validity and reliability of a novel instrumented one-legged hop test in patients with knee injuries

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ABSTRACT

Background: Conventional one-legged hop tests simply evaluate the total hop distance, thus neglecting important temporal and spatial parameters related to the strategy of execution, such as foot contact time.

Aim: To examine the validity and reliability of an instrumented one-legged hop test, the “four hops, three contacts” (4H3C) test, in patients with knee injuries.

Methods: The 4H3C test consists of four consecutive one-legged hops, of which individual hop distance and foot contact time are recorded by a validated floor-based photocell system. We examined the test–retest reliability, discriminant validity (involved vs. uninvolved side) and convergent validity (relation with maximal voluntary strength) of consecutive hop distance and foot contact time parameters in 50 patients with unilateral knee injuries.

Results: Test–retest reliability was very high for hop distance (intraclass correlation coefficients: 0.91 to 0.97) and high for contact time variables (intraclass correlation coefficients: 0.75 to 0.88). The difference between the involved and the uninvolved side was significant for all hop distance and contact time parameters ($p < 0.05$). Maximal voluntary strength was correlated to both hop distance ($r = 0.67$; $p < 0.001$) and contact time ($r = -0.42$; $p < 0.01$) variables.

Conclusion: The 4H3C is a valid and reliable test for the evaluation of single hops in patients with knee injuries and may be useful in sport and clinical settings. The interpretation of foot contact time data requires however some caution.

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1. Introduction

Performance-based measures of physical function are widely used in orthopedics and sports medicine for evaluative, discriminative or predictive purposes [1–3]. For example, these data can be used to quantify the functional deficit consequent to injury and/or surgery [4], assess the effectiveness of a rehabilitation program [5–7], discriminate between different groups of subjects or conditions (e.g., involved vs. uninvolved limb) [8,9] and evaluate the readiness of an individual to return to sport [10,11].

The single, triple or quintuple one-legged hop tests have gained popularity in the clinic because they are easy to administer and do not require expensive equipment [4,7,8,11–14]. However, only the total hop distance is usually quantified, thereby

Abbreviations: 4H3C, four hops three contacts; ACL, anterior cruciate ligament; C1, contact one; C2, contact two; C3, contact three; CI, confidence interval; H1, hop one; H2, hop two; H3, hop three; H4, hop four; ICC, intraclass correlation coefficient; SD, standard deviation; TE, typical error.

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neglecting important variables related to the strategy of execution, such as foot contact times and hop distances for the different hops of a series. Therefore, we propose here a novel, instrumented one-legged hop test, called the “four hops, three contacts” (4H3C) test, which involves the use of a valid and accurate floor-based photocell system (Optogait, Microgate, Bolzano, Italy) [9,15]. In comparison to the conventional hop tests [4], the instrumented 4H3C test would allow a more comprehensive assessment of the distance of each of the four consecutive hops together with the three associated foot contact times. This could offer potentially useful insights into the strategy of test execution. For example, quantification of foot contact time may reveal that the foot of the involved limb remains longer on the ground compared to the uninvolved limb, despite a comparable total hop distance for the two sides.

Therefore, the aim of this methodological study was to examine the reliability and validity of the 4H3C test in individuals with unilateral knee injuries. Foot contact time and hop distance of single and multiple hops were evaluated for test–retest reliability, discriminant validity (comparison between involved and uninvolved side) and convergent validity (correlation with maximal voluntary strength).

2. Methods

The study protocol was approved by the Kantonale Ethikkommission Zürich (reference: KEK-ZH-Nr. 2013-0240), and was carried out at the Schulthess Clinic in Zurich, Switzerland. Written informed consent forms were signed by all subjects prior to enrollment.

2.1. Patients

The main inclusion criteria were the presence of one or more of the following knee injuries: anterior cruciate ligament (ACL) tear, tibiofemoral/patellofemoral cartilage damage and medial/lateral meniscus tear. The main exclusion criteria were the current presence of back, knee, hip or ankle pain on either of the two sides, acute musculoskeletal injury and previous open surgery on the uninvolved side. The estimated sample size for test–retest reliability analyses was 46 subjects with a minimally acceptable level of reliability of 0.8 [16]. With regard to possible drop outs, 50 patients with different knee injuries were enrolled in this study (21 women and 29 men, mean age \pm SD: 27 ± 6 years, height: 176 ± 9 cm, weight: 74 ± 13 kg, proximal thigh circumference: 53 ± 4 cm, femur length: 47 ± 5 cm, tibia length: 41 ± 4 cm). With respect to knee injury, 27 patients (54%) had an isolated ACL tear, seven (14%) had an isolated cartilage damage, six (12%) had an isolated meniscal tear, and 10 (20%) had a combination of knee injuries (ACL tear, cartilage damage, meniscal tear). With respect to surgery, 24 subjects (48%) had ACL reconstruction (bone–patellar tendon–bone or hamstring autografts), five (10%) had cartilage repair (autologous chondrocyte implantation, autologous matrix-induced chondrogenesis, microfracturing or cartilage shaving), five (10%) had meniscus repair, one (two percent) had ACL reconstruction and meniscus repair and 15 (30%) had no surgery. On average, surgical patients were tested 223 ± 30 days after ACL reconstruction or cartilage repair and 159 ± 55 days after meniscus repair. Non-surgical subjects were tested 573 ± 688 days after the injury. The mean score for the Tegner activity scale [17] at the time of knee injury was 5.9 ± 1.9 (range: 0 to 10).

2.2. Experimental protocol

Patients were asked to participate in two identical testing sessions (test and retest, duration: one hour) that were separated by 2 to 7 days. Each session included two main assessments that were conducted unilaterally for the involved and uninvolved side: the 4H3C test for the evaluation of hop distance and foot contact time and an isometric test for the evaluation of lower extremity maximal voluntary strength. Within each test, the uninvolved side was always tested before the involved one [11,13]. Subjects wore their own sport shoes and received consistent verbal encouragement during testing. They were also instructed to avoid exhausting exercise the day before the assessments.

2.2.1. Assessment of 4H3C parameters

Following a general warm-up that included five minutes of stationary cycling at one watt per kilogram of body weight, subjects were asked to complete the 4H3C test. The 4H3C test protocol is similar to the one originally described by Noyes et al. [4] with the exception of the number of hops (four vs. three), the measurement tool (photocells vs. tape measure) and the inclusion of additional outcomes. A validated floor-based photocell system (Optogait, Microgate, Bolzano, Italy) was used to measure hop distances and foot contact times of single and multiple hops (Fig. 1A). Accordingly, H1 was defined as the distance of the first hop, H2 as the sum of the distance of the first and second hop, and so on for H3 and H4 (Fig. 1B). In the same way, C1 was defined as the foot contact time between the first and second hop, C2 as the contact time between the second and third hop, and C3 as the contact time between the third and fourth hop (Fig. 1B). Ten transmitting and 10 receiving bars (each with a length of one meter) were placed in parallel along a virtual corridor of 10 m, with a lateral distance of approximately one meter between transmitting and receiving units. Each one-meter transmitting unit (sampling frequency: one kilohertz) contains 96 light emitting diodes that are positioned three millimeters from ground level at one-centimeter intervals. A webcam connected to the Optogait system and positioned one meter behind the starting point was used to control feet and body positions during testing. At the beginning of the test, subjects were asked to stand on the starting line with the tested foot, while the untested foot was lifted off the ground, and then to perform four consecutive hops on the same leg with the instruction to “hop as far as possible four times”.

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