RELIABILITY OF 3D FRONTAL PLANE KNEE AB/ADDUCTION RANGE OF MOTION DURING RUNNING IN YOUNG ATHLETES

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This study quantified within-session and between-session reliability of 3D frontal plane knee ab/adduction range of motion during the stance phase of running gait calculated for 18 long term athlete development programme participants (10 males and 8 females, 11.5 ±1.4 years) during two testing sessions (spaced 10 weeks apart). Average mean differences in frontal plane knee ab/adduction between running trials (for the right or left side) within a session (week 1 or week 10) ranged from 0.2 to 7.2% (ES 0.01–0.26) which were acceptable differences. However, average mean differences between sessions for running trials (for the right or left side) ranged from 0.1 to 20% (ES 0.01–0.6). The mixed model resulted in estimates of knee ab/adduction range of motion for effects of limb side (3.6°), session (2.8°), run trial (0.2°) and subjects (4.5°). Within-session ICCs ranged from 0.80 to 0.92 and between-session ICCs ranged from 0.51 to 0.73. Based on these ICCs, within-session reliability of frontal plane knee ab/adduction is good and between-session reliability is average to good.

KEYWORDS: running, children, reliability, lower extremity, 3D kinematics.

INTRODUCTION: Screening of individuals for risk of lower limb injury and as a means to optimising performance has become common, particularly in professional sport, but also at other competitive and recreational levels (Mottram & Comerford, 2008). When assessing the lower extremity, the use of functional gait screening to evaluate movement quality is becoming common place. During assessments of gait, clinicians typically evaluate dynamic lower extremity alignment. Poor dynamic alignment has been described as a combination of excessive pelvic drop, hip adduction, internal rotation and knee valgus (Earl, Monteiro, & Snyder, 2007; Powers, 2003; Sahrmann, 2002; Willson & Davis, 2009). Poor frontal plane knee control observed during activities such as running, squatting and landing, is considered a key risk factor for the development of common injuries such as patellofemoral dysfunction. Clinically this is often observed as increased stance phase valgus angle at the knee (Powers, 2003).

Few studies have investigated the reliability of frontal plane kinematics during gait, and none have assessed children. However, it is crucial to know if kinematics are consistent enough from day to day for making clinical decisions. Reliability refers to whether a specific measurement tool produces consistent outcomes during repeated measures of the same variable (Clark, 2001). Highly sensitive sports science measurements are characterised by little variation in consecutive measures of performance (Hopkins, 2000). A change in performance due to an intervention has to be greater than the normal day-to-day training variation before coaches can conclude that the intervention has had a meaningful impact on the athlete's performance (Soper & Hume, 2004). For a performance test to be valuable it must be specific enough to measure the performance variable of interest and reliable enough to detect the relatively small differences in performances that are beneficial to elite athletes (Schabort, Hawley, Hopkins, & Blum, 1999). Utilisation of a reliable assessment tool helps ensure that variations between measurements are attributed to changes in the variable being measured (Bolgla & Keskula, 1997; Clark, 2001). Furthermore, the reliability of tests needs to be established if they are to be used in longitudinal studies evaluating injury risk or the effect of rehabilitation interventions.

The purpose of this study was to investigate within-session and between-session reliability of 3D frontal plane knee ab/adduction range of motion during the stance phase of treadmill running in healthly young athletes.

METHODS: Eighteen young athletes (10 male and 8 female, 11.5 ±1.4 years, 1.53 ±0.12 m, 44 ±7.9 kg) were recruited from an existing long-term athletic development (LTAD) programme designed to develop all-round sporting ability. All athletes were injury-free at the time of testing. Data were collected during two sessions 10 weeks apart. During each session participants underwent a treadmill-based assessment of running kinematics. A nine-camera motion analysis system (Qualysis Medical AB, Sweden) recorded lower body 3D kinematics. Twenty-one retro-reflective markers were secured to specific lower extremity anatomical locations. Two cluster marker sets (four markers attached to a plastic shell) were also attached to the thigh and shank of each leg. Children ran for five minutes at a self-selected speed (2.19 ±0.22 m/s) and kinematic data were collected in two 30-second increments at two-minute intervals. Anatomical markers were tracked using the Qualysis motion capture software and exported to Visual 3D (C-Motion Inc, USA) for calculation of relevant kinematic data. Kinematic data 'text' files were imported into Labview (National Instruments, USA) for calculation of range of motion via maximum and minimum joint angles during the stance phase of ten running strides. To summarise, each athlete completed two running trials at session 1 and session 2. Ten continuous steps for each limb were extracted from each trial for sequential analyses.
Statistical Analysis System (SAS) (SAS Institute Incorporated, USA) was used to calculate descriptive statistics including means and standard deviations (spread of results among participants) and within-session and between-session reliability of 3D frontal plane knee ab/adduction range of motion. Data were log transformed to provide measures of reliability (performance consistency) using a repeated measures analysis of variance. Reliability measures included the difference in the mean as a percentage, and Cohen's effect sizes (ES). Effect sizes are interpreted as <0.2 as trivial, <0.41 as small, 0.41-0.7 as moderate, and >0.7 as large (Hopkins, 2002). Variability measures included intra-class correlation coefficients (ICC), and typical error of measurement as a coefficient of variation percentage (Hopkins, 2000) estimated from the knee ab/adduction range of motion (discrete value). The ICC classifications of Fleiss (1999) were used to describe the magnitude of ICC values (<0.4 as poor, 0.40-0.75 as fair to good and 0.75 as excellent). A mixed modelling approach using SAS allowed quantification of both fixed effects (e.g. trial number, week of testing) and random effects (e.g. individual identity) and included variances and co-variances caused by both between- and within-subject factors (Hopkins, 2002). ICCs were calculated for a variety of steps (1 to 25).

RESULTS AND DISCUSSION: Kinematics in all three planes were measured, however, given the proposed links between poor frontal plane knee control and the development of lower extremity injuries (Powers, 2003), the focus was placed on the assessment of knee ab/adduction range of motion. Within-session descriptive and reliability statistics, including 90% confidence limits (90%CL), for knee ab/adduction range of motion for all participants are presented in Table 1. Between-session, within trial statistics for each limb are presented in Table 2. Within-session average mean differences between running trials for each limb ranged from 0.2 to 7.2%, which were acceptable differences. However, average mean differences between sessions for running trials for a given limb side ranged from 0.1 to 20%.
A standard error of measurement of 10% or less is considered small in pure test-repeats of three or more trials (Bennell, Crossley, Wrigley, & Nitschke, 1999). Our typical errors expressed as CV% were 10-13% indicating moderate variability for knee ab/adduction between subjects. Although the CV%s were moderate, the magnitude of the angles was relatively small, usually less than a few degrees. Variability in 3D kinematics may be due to errors in measurement, marker replication and movement, and variability of human locomotion. It is difficult to seperate these and therefore the variability reported in this study includes all contributions.

Table 1. Within-session statistics, including 90%CL, for frontal plane knee ab/adduction range of motion during the stance phase of running for healthly young athletes (n=18).

	Session 1		Session 2	
	Right	**Left**	**Right**	**Left**
Trial 1 mean ±SD (degrees)	6.8 ±2.0	6.8 ±2.9	8.1 ±2.2	6.8 ±2.4
Trial 2 mean ±SD (degrees)	7.4 ±2.5	6.8 ±2.7	8.4 ±2.6	7.2 ±2.4
ES (within-session, between-trials)	0.26	-0.01	0.10	0.15
Change in mean % (90%CL)	7.2 (0.5 to 14.4)	0.2 (-5.5 to 6.2)	2.1 (-5.1 to 9.9)	5.4 (-2.0 to 13.4)
Typical error as a CV% (90%CL)	11.8 (9.2 to 16.9)	10.5 (8.2 to 15.0)	13.5 (10.5 to 19.5)	13.4 (10.4 to 19.2)
Total error (%)	12.7	10.2	13.2	13.6
Intraclass r (90%CL)	0.87 (0.73 to 0.94)	0.92 (0.82 to 0.96)	0.80 (0.59 to 0.91)	0.90 (0.78 to 0.96)

Table 2. Between-session statistics, including 90%CL, for frontal plane knee ab/adduction range of motion during the stance phase of running for healthly young athletes (n=18).

	Right		Left	
	Trial 1	**Trial 2**	**Trial 1**	**Trial 2**
Session 1 mean ±SD (degrees)	6.8 ±2.0	7.4 ±2.5	6.8 ±2.9	6.8 ±2.7
Session 2 mean ±SD (degrees)	8.1 ±2.2	8.4 ±2.6	6.8 ±2.4	7.2 ±2.4
ES (for a trial, between-sessions)	0.63	0.40	0.01	0.16
Change in mean % (90%CL)	20.3 (9.4 to 32.2)	14.6 (0.7 to 30.3)	0.1 (-10.7 to 12.2)	5.4 (-7.8 to 20.4)
Typical error as a CV% (90%CL)	17.7 (13.7 to 25.6)	24.9 (19.1 to 36.5)	21.8 (16.8 to 31.8)	25.9 (19.8 to 38.1)
Total error (%)	22.8	26.7	21.1	25.5
Intraclass r (90%CL)	0.66 (0.35 to 0.84)	0.51 (0.13 to 0.76)	0.73 (0.46 to 0.87)	0.61 (0.28 to 0.81)

The mixed model resulted in knee ab/adduction estimates for effects of limb side (3.6°), session (2.8°), trial (0.2°) and subjects (4.5°). Analyses of ICCs and standard deviations (SD) expressed as degrees showed that for most variables at least 10 steps per running trial were needed. Knowledge of the variation in variables within a session and between sessions allows an estimation of the number of subjects and numbers of trials when designing experiments. For an experimental study with parallel groups (control and intervention), the number of subjects required can be determined by the equation 2*(1-ICC)*272 where the smallest worthwhile effect is 0.2 (Hopkins, 2000). The number of subjects in each group varies depending on the number of steps analysed and the subsequent ICC of the variable to be measured. For example, if three steps were analysed for a variable giving an ICC of 0.71 then the equation 2*(1-0.71)*272 results in 158 subjects in each group. If ten steps were analysed for a variable giving an ICC of 0.78 then the equation 2*(1-0.78)*272 results in 119 subjects in each group. If ten steps were analysed for a variable giving an ICC of 0.96 then the equation 2*(1-0.96)*272 results in 22 subjects in each group.

A change and/or reduction in frontal plane knee motion when running is potentially important for designing injury prevention interventions. It is therefore essential that we have a good appreciation of how reliably this can be measured. These results demonstrate that knee ab/adduction can be reliably measured within acceptable limits both within-sessions and between-sessions. However, it should be noted that to achieve this level of reliability at least 10 steps should be analysed.

CONCLUSION: Within-session and between-session reliability of knee ab/adduction range of motion during the stance phase of running in a young athlete population demonstrated average to good reliability. Knee ab/adduction range of motion could be a useful clinical screening tool.

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