ISB 2013 BRAZIL
24th CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

THE EFFECT OF THIGH SKIN MARKER CLUSTER CONFIGURATION ON KNEE VALGUS MEASUREMENT IN VERTICAL DROP JUMPING: AN IMPLICATION TO ACL INJURY RISK FACTOR STUDY

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SUMMARY

The aim of this study is to investigate the effect on knee valgus measurement of variations in thigh skin marker cluster configuration. Nineteen elite female handball players and twenty-two elite female football players (n = 41) performed a vertical drop jumping motion in a skin marker based-motion capture system. Five different thigh skin marker cluster configurations were compared. The variation in thigh skin marker cluster configuration was found to cause a significant difference in peak valgus measurement.

INTRODUCTION

Skin marker based-motion capture is often used to measure the knee valgus to understand the jumping motion [1] and to identify the risk of anterior cruciate ligament (ACL) injury [2, 3]. Methodological variations cause differences in experimental results, which may undermine the clinical application of motion analysis [4]. The variation in ranking of the players in term of knee valgus measurement may lead to variation in the definition of which players are at high or low risk.

To calculate the knee joint kinematics, it is crucial to attach the thigh and shank skin markers to the position where soft tissue artifact (STA) is globally minimized [5]. For the shank, Peters et al. [6] reported that the markers located on the anterior tibial crest and malleoli would be least susceptible to STA. For the thigh, no general agreement has been reached on the cluster configuration because the large different STA between subjects is observed [7].

Previous ACL injury studies use a three skin markers cluster configuration on thigh [2, 3]. However, the number of markers should be at least four to give an optimal motion tracking [5]. Adding extra skin marker is challenging, because most of the areas in thigh have high STA, especially in proximal area [7]. The Hip Joint Center (HJC) could be a suitable additional marker position because its position is based on the markers on the pelvis skin markers which have high correlation to the actual underlying bone movement [8].

The present study investigates the effect on knee valgus measurement of variation in thigh skin marker cluster configuration. The variations are the inclusion of HJC and the number of skin markers in the cluster configuration.

METHODS

Nineteen elite female handball players and twenty-two elite female football players (21.6±4 years old, 168±5 cm, 66±8 kg) were invited to be the subject of this study (n = 41). The subjects performed vertical drop jumping in a biomechanics laboratory. Sixteen 480 Hz infrared cameras (Oqus, Qualisys, Gothenburg, Sweden) recorded the movement of the skin markers over pelvis, thigh and shank. The thigh skin markers included Lateral Epicondyle (LE), Anterior Thigh (AT), Greater Trochanter (GT), Distal Anterior Thigh (DAT) and Lateral Thigh (LT) as shown in figure 1. And the ground reaction force was recorded by a force plate (AMTI, Massachusetts, USA) collecting at 960 Hz. A standing static calibration was performed to determine the anatomical coordinate systems. Then, the subjects were asked to drop down from a 30cm high box and immediately perform a maximum vertical jump.

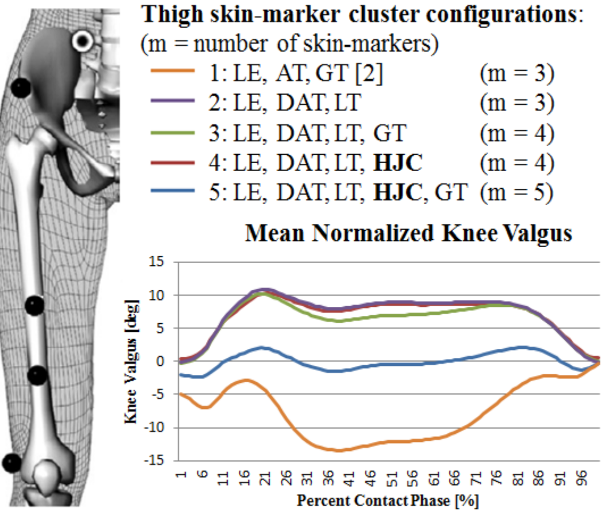

Figure 1: Thigh skin marker cluster configurations and normalized knee valgus of different cluster configurations.

The contact phase was defined as the period where the unfiltered vertical ground reaction force exceeded 20 N. Skin marker trajectories were filtered and interpolated using Woltring’s smoothing spline in the cubic mode with 15 Hz as the cut-off frequency [9]. The hip joint center was calculated using the regression method proposed by Bell et al. [10]. The knee joint center was defined according to the Davis et al. [11] and the ankle joint center was defined according to Eng and Winter [12]. Anatomical coordinate systems of the thigh and shank were determined from the standing static calibration. The vertical axis was defined in the direction from distal to proximal joint center, while the anterio-posterior axis was defined perpendicular to the vertical axis with no mediolateral component. The third axis was the cross product of the vertical and antero-posterior axis. Consequently, all segments had neutral int-external rotation in the standing static calibration. Technical thigh and shank segment coordinate systems were found using an optimization procedure involving singular value decomposition [13]. The knee joint kinematics was calculated by the convention suggested by Grood and Suntay [14] under 5 different thigh skin marker cluster configurations as shown in figure 1.

Statistical analysis was performed in SPSS 18 (SPSS Inc., Chicago, IL, USA). The peak knee valgus measurement of contact phase was compared across the 5 different thigh skin marker cluster configurations in repeated-measures ANOVA with post-hoc Bonferroni. To assess whether skin marker cluster configuration affected the ranking of subjects, Spearman's rank correlation coefficient was calculated for the peak knee valgus measurements. Then, the cluster configurations were grouped by no significant difference on peak knee valgus measurement and Spearman's rank correlation coefficient (> 0.85). Furthermore, the inclusion of HJC and the number of skin markers (m) were examined as a fixed factor by two-way ANOVA.

RESULTS AND DISCUSSION

The Spearman's rank correlation coefficients and results of post-hoc Bonferroni are shown in table 1. The cluster configurations are divided into two groups for further discussion. Group A consists of cluster configuration 2, 3 and 4, and group B consists of cluster configuration 1 and 5. No significant effect was found in the peak knee valgus measurement with the inclusion of HJC and the number of skin markers as a fixed factor.

Table 1: The Spearman's rank correlation coefficients on different combinations of thigh skin marker cluster configurations

Thigh skin marker cluster configuration	2	3	4	5
1	.477*	.435*	.534*	.865
2		.975	.959	.639*
3			.952	.634*
4				.760*

* Significant difference on peak knee valgus measurement ($p<0.05$)

For group A, all the cluster configurations include the three distal thigh skin markers which are LE, DAT and LT. No matter which marker on the proximal thigh (GT or HJC) was added to the cluster configuration, there was no significant difference compared with the cluster configuration with the three distal markers. The Spearman's rank correlation is high among these three cluster configurations. Furthermore, good agreement on the waveform could be visually observed (Figure 1). It can be concluded that no significant difference was found when one or no proximal thigh marker is added to the three distal thigh skin markers cluster configuration.

For group B, surprisingly, a high Spearman's rank correlation and no significant difference were found even cluster configuration 1 and 5 were very different. However, deviation can be seen from the entire waveform (Figure 1). A systemic difference was observed in the first 15% of the contact phase. The deviation increased to more than 10 degrees in the mid-contact phase. Further investigation on the entire waveform is needed to achieve a better understanding on the effect.

The Spearman's rank correlation was in some cases lower than 0.5, which means the ranking of the players based on the peak knee valgus measurement was affected by the variation in cluster configurations. However, neither the inclusion of HJC nor the number of skin markers was not the factor of making difference.

One weakness of this study is the absence of a golden standard. The accuracy of the measurement could not be examined in this study. Biplanar videoradiography could be a possible solution to provide a non-invasive golden standard in jumping motion [15]. Only peak knee valgus measurement was investigated in the study. Further study on the knee valgus measurement at the other time points, such as initial contact, would probably give a better understanding on the effect of cluster configuration.

CONCLUSIONS

The variation in thigh skin marker cluster configuration was found to cause a significant difference in peak knee valgus measurement. However, neither the inclusion of HJC nor the number of skin markers causes any significant effect in peak knee valgus measurement. Further study is needed.

ACKNOWLEDGEMENTS

The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sports Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & the Confederation of Sport and Norsk Tipping AS.

REFERENCES

1. Chappell JD and Limpisvasti O, *Am J Sports Med.* **36**:1081-1086, 2008.
2. Hewett TE et al., *Am J Sports Med.* **33**:492-501, 2005.
3. Myer GD et al., *Br J Sports Med*. **45**:238-244, 2010.
4. Gorton G et al., *Gait Posture.* **29**:398-402, 2009.
5. Cappozzo A et al., *IEEE Trans Biomed Eng*. **44**:1165-1174, 1997.
6. Peters A et al., *Gait Posture*. **29**:42-48, 2009.
7. Stagni R et al., *Clin Biomech*. **20**:320-329, 2005.
8. Drerup B and Hierholzer E, *J Biomech*. **20**:971-977, 1987.
9. Woltring HJ, *Adv Eng Software*. **8**: 104-113, 1986.
10. Bell et al., *J Biomech*. **23**:617-621, 1990.
11. Davis III RB et al., *Hum Mov Sci*, **10**:575-587, 1991.
12. Eng JJ and Winter DA, *J Biomech.* **105**:753-758, 1995.
13. Soderkvist I and Wedin PA, *J Biomech.* **26**:1473-1477, 1993.
14. Grood ES and Suntay WJ, *J Biomech Eng.* **105**:136-144, 1983.
15. Miranda DL et al., *J Biomech*. **46**:567-573, 2013.