Agreement between lower-limb NJM derived using 'Theia3D' and marker-based methods during the Snatch

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Summary

Net joint moments (NJM) of healthy nationally competitive weightlifters were compared when 3D force plate (Kistler) data were combined with either 'Theia3D' (Theia Markerless Inc., Kingston, ON, Canada) or marker-based motion capture during the pulling phases of the snatch. Theia3D showed a good level of system agreement, with root mean square errors (RMSE) of 0.32 and 0.28 Nm•kg^{-1} for the hip and knee NJM about the flexion-extension axis, respectively, during the entire snatch-pulling phase. Theia3D appears to be a promising tool in the derivation of NJM in the applied field.

Introduction

The snatch comprises two distinct pulling phases where lower-limb NJM are of interest, due to their contributions to the vertical component of ground reaction force (1). Whilst lower-limb kinematics remain consistent due to task constraints, kinetics are load-dependent (2). Training and competition analysis has shown a strong correlation between increased hip and knee NJMs to total system mass (2,3), but robust recording of subject kinematics in competition is not always feasible. Theia3D, a deep learning-based pose estimator, has shown very good system agreement for kinematic analysis (4) but has yet to be fully tested on dynamic tasks in non-laboratory conditions. This study evaluates the agreement between Theia3D and marker-derived NJM during the snatch at near maximal load.

Methods

Three healthy male competitive weightlifters were recruited (25 ± 2 years, 174 ± 9 cm, 82 ± 7 kg, 103 ± 15kg 1-RM) to complete one repetition at 80 and 85% of 1-repetition maximum in the snatch. A 200-Hz synchronized Qualisys motion capture system was used, including sixteen infrared cameras and eight video cameras. Two Kistler 9260A force plates were used, sampling at 1000 Hz. Video data were processed through Theia 3D v2024.1.17, with an 8-Hz smoothing frequency. NJM was calculated in Visual3D v2024.09.5, for left and right hip and knee joints at the first pull (initial displacement to initiation of transition), second pull (end of the transition to the beginning of turnover) and entire pulling phase. Both systems derived NJM were filtered with a 6-Hz Butterworth filter. RMSE was calculated between the marker and Theia3D-derived NJM for the first and second pull and total pull duration. RMSE was then averaged across all participants for both loading conditions.

Results and Discussion

Theia3D demonstrated relatively low RMSE values for the NJM of the hip and knee during the snatch pulling phases (Table 1). As a percentage of the peak NJMs averaged between systems, the knee joint RMSE for the entire pull is 11.3% and 9.6% for the knee and hip, respectively.

Relative joint moment	RMSE ± SD (Nm•kg^{-1})		
	First pull	*Second pull*	*Entire pulling phase*
Knee	0.19 ± 0.16	0.35 ± 0.23	0.28 ± 0.19
Hip	0.35 ± 0.25	0.27 ± 0.17	0.32 ± 0.21

Table 1: RMSE ± SD of the normalized NJM (Nm•kg^{-1}) of the hip and knee during 80 & 85% snatch

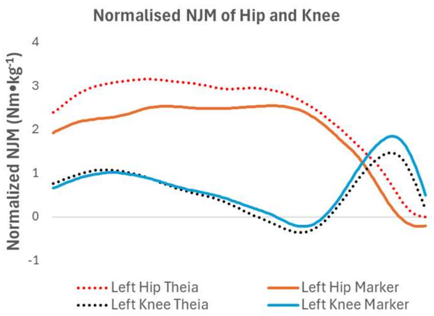

Figure 1: Theia3D and marker-based left hip & knee NJM during a single 85% snatch

Weightlifting success is entirely determined by the load lifted, and with increased load, intersegmental forces increase (3). We observed good agreement between the NJMs computed with Theia3D and traditional marker-based methods, suggesting great promise for the utility of unobtrusive markerless technologies in weightlifting. If accurate markerless analyses can be conducted on mass scale, coaches and athletes could be provided with performance-critical information that could benefit long-term athletic development. Ultimately, this could lead to more successful training and competition performance in weightlifting.

Conclusions

Within the population used in this study, the NJMs computed using Theia3D-derived kinematics can provide comparable data to traditional marker-based methods and thus could be used to interpret snatch pulling phase NJM without any markers or instrumentation being placed on the athlete.

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