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ESTIMATION OF GRIP FORCE USING MOTION ANALYSIS AND PRESSURE SENSITIVE SENSORS

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SUMMARY
In this work in progress we examine the validity of using motion capture and pressure sensitive sensors to estimate resultant forces when gripping a cylinder. First results indicate a mixture of relatively small and relatively large errors. We speculate that factors contributing to these observations might include sensor resolution (0.5 sensor/cm^2) and sensor time delays.

INTRODUCTION
Numerous motor actions involve manipulating an object with two hands. Performing inverse dynamics calculations for the upper limbs in such motor actions, calls for a way to measure the resultant force between each hand and the object in question. Here we examine the validity of using motion capture and pressure sensitive sensors to estimate resultant forces when gripping a cylinder. Both quasi-dynamic and dynamic conditions were investigated.

METHODS
Grip forces in seven different test conditions were estimated using: (1) 3D marker data collected with an optoelectronic motion analysis system with 12 infrared cameras (Oqus 4 camera series, Qualisys AB, Gothenburg, Sweden), operating at 250 Hz; and (2) pressure distribution data collected with capacitive sensor mat Elastisens S2073_11 (226 x 56.5 mm) (Pliance-X System, Novel GmbH, Munich, Germany).

All test conditions involved gripping a cylinder with the capacitive sensor mat attached along the perimeter and an external weight hanging by a rope at one end (Figure 1). The following tasks were performed with one hand: (test condition 1-2) holding the cylinder horizontal with an external weight of 0.5 kg (1) and 1 kg (2); (test condition 3-4) raising and lowering the cylinder repetitive times while keeping the cylinder with an external weight of 0.5 kg (3) and 1 kg (4) horizontal. Test conditions 5-6 involved the same tasks as in test conditions 2 and 4 but were performed with two hands. In test condition 7 the task was to vary the grip force while keeping the cylinder with an external weight of 1 kg horizontal using both hands.

A model of a cylinder of known diameter (18mm) containing a list of all 64 cells in the sensor mat, their position in a local coordinate system, and their normal vector, was fitted to marker data by using point correspondence [1]. The normal force vector for each cell was computed by multiplying a radial unit vector (origin at the center of the cell) with pressure distribution data and the cell area. The resultant force was computed by adding all normal force vectors and calculating the norm. Calculations were done using Matlab (Version 7.14.0, The Mathworks, Inc., Natick, USA).

To examine the validity of using motion capture and pressure sensitive sensors to estimate the resultant force, values computed by multiplying the mass of the cylinder and external weight by the acceleration and gravity was used as reference. RMS error (RMSE) and coefficient of variation (CV) was used as measures of differences between the two sets of force values.

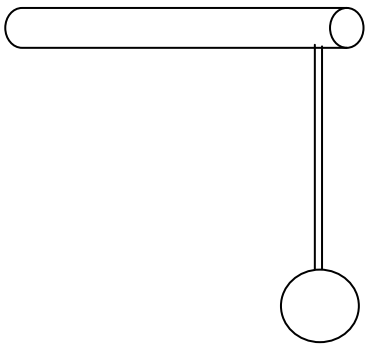

Figure 1: Cylinder with external weight.

RESULTS AND DISCUSSION
Table 1 shows RMSE and CV values for the 7 test conditions investigated. RMSE and CV values were relatively low when holding the cylinder with one hand (test condition 1 and 3) but surprisingly the corresponding values when using both hands was found to be relatively large (test

condition 5). Mixed results was found when moving the cylinder vertically and varying the grip pressure, while holding the grip with two hands, produced large errors (test condition 7).

CONCLUSIONS

This work in progress shows a mixture of relatively low and relatively high discrepancies between the forces estimated by using marker and pressure distribution data and reference force values. Possibly, the sensor resolution (0.5 sensors/cm^2) and sensor time delays might explain a substantial part of these discrepancies.

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REFERENCES

1. Soderkvist I & Wedin PA, *Journal of Biomechanics.***26**: 1473-1477, 1993.

Table 1: Root mean square error (RMSE) and coefficient of variation (CV) for seven test conditions..

Test condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**
RMSE	0.5390	3.1945	1.4272	0.6635	8.9829	3.9261	13.8195
CV	0.0628	0.7285	0.1126	0.0646	0.9724	0.4374	0.9127