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MATHEMATICAL MODEL TO OPTIMIZE GOALKEEPERS' JUMPING.

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SUMMARY

The purpose of this study was to analyze the ground reaction forces and power output during near maximal jumps and to develop a mathematical tool that coaches can use to optimize a goalkeeper's performance in game situations. Six male volunteers participate in this study. Kinematic data and ground reaction forces during these jumps were collected. Each goalkeeper performed nine jumping trials. Net ground reaction force vs. time curves and peak forces vs. net impulses were extracted from each jump. Net power output and total work for each jump were also determined using the ground reaction force and the velocity of the centre of mass of the subject, and by integration of the power-time curve, respectively. The Pearson Correlation coefficient was then calculated between peak force and peak power and between impulse and work. There was a distinct difference between goalkeepers and the non-goalkeepers. For goalkeepers, peak net ground reaction forces occurred in the concentric phase, while for non-goalkeepers it occurred in the eccentric phase of jumping. Peak forces and impulses were significantly greater in the goalkeepers than the non-goalkeepers. The correlations between peak force and peak power and between impulse and work were R=0.84 and R=0.93 respectively. We conclude that force-time and power-time curves of goalkeepers and non-goalkeepers differ substantially, and that these differences might help identify good goalkeeping and strategies to improve their training.

INTRODUCTION

In soccer, goalkeepers have specific characteristics regarding their physical preparation, technique and tactics. The training of a goalkeeper should focus on these characteristics and develop them in order to optimize performance in game situations. Specifically, goalkeepers need to execute a lot of jumps in training to increase muscle power, as jumping ability is a pre-requisite for an effective goalkeeper.

It would be of great help if we could evaluate a goalkeeper's muscle forces, power output, and joint coordination in training sessions in a straight forward manner. However, during training, we cannot ask them to leave their regular routine and spend time to perform laboratory tests. Therefore, the purpose of this study was to analyze the ground reaction forces and power output of the legs during near maximal jumps where goalkeepers had to catch a ball. We used goalkeepers of varying ability to potentially identify characteristics of forces and power output that are associated with good goalkeeping. These results, we hoped, might then allow for feedback to optimize the performance of goalkeepers in games. The ultimate goal of the present project is to develop a mathematical tool that coaches can use to optimize a goalkeeper's performance in game situations.

METHODS

Six male volunteers gave written informed consent to participate in this study (when they were less than 18 years old, their parents signed the document). Subjects were four goalkeepers (age = 17.0±1.8 years; training time = 8.5±2.6 years) and two subjects with no goalkeeping experience (age = 26.0±7.1 years). Kinematic data of jumps aimed at reaching a ball were collected using an eight high-speed video camera system (Motion Analysis Corporation®) at a sampling rate of 240 Hz. Ground reaction forces during these jumps were collected and synchronized with the kinematic data using a force plate (Kistler®) at a sampling rate of 2400 Hz. Retro-reflective markers were attached to the skin on the foot, shank, and thigh of the right lower leg, and the pelvis to measure the three dimensional movement of the ankle, knee, and hip joint (Park & Stefanyshyn, 2011). Additionally, markers were positioned on top of the right trochanter, medial and lateral femoral condyles, and medial and lateral malleoli to define the joint centers. Joint center markers were used for calibration, but were removed for the jumping trials.

Each goalkeeper performed nine jumping trials, simulating a real game situation where they had to catch a ball to the side and slightly overhead. The ball was thrown by an investigator in such a manner that a "maximal" effort jump was required by the goalkeepers to catch the ball with both hands. Subjects performed this task by making a side step (onto the force platform) from a two-legged symmetric stance facing the ball-thrower, and then jumping sideways and up to reach the ball. Trials in which subjects did not hit the force platform or could not reach and catch the ball safely with both hands, were rejected.

Force data were smoothed using a low-pass digital filter with a cutoff frequency of 30 Hz. The beginning and end of foot contact was identified from the force plate records. Net ground reaction force vs. time curves were then plotted to visually analyze patterns of behavior of each subject and all jumps. For quantitative comparisons, peak forces, net impulses and contact times were extracted from each jump.

Then, we plotted peak forces as a function of net force impulses for each subject, and calculated the median and 95% confidence interval for the nine trials of each subject. Net power output and total work for each jump were also determined using the ground reaction force and the velocity of the centre of mass of the subject (approximated by a marker on the sacrum of each subject), and by integration of the power-time curve, respectively. The Pearson Correlation coefficient was then calculated (Matlab®) between peak force and peak power and between impulse and work.

RESULTS AND DISCUSSION

There was a distinct difference between the net ground reaction force-time curve patterns between the goalkeepers and the non-goalkeepers (Figure 1). For goalkeepers, peak net ground reaction forces occurred in the concentric phase (late in the jump), while for non-goalkeepers it occurred in the eccentric phase of jumping (early in the jump). Furthermore, the net ground reaction force vs. time curves exhibited one distinct peak for the goalkeepers and two distinct peaks for the non-goalkeepers.

Peak forces and impulses of the net ground reaction force were significantly greater in the goalkeepers than the non-goalkeepers (Figure 2).

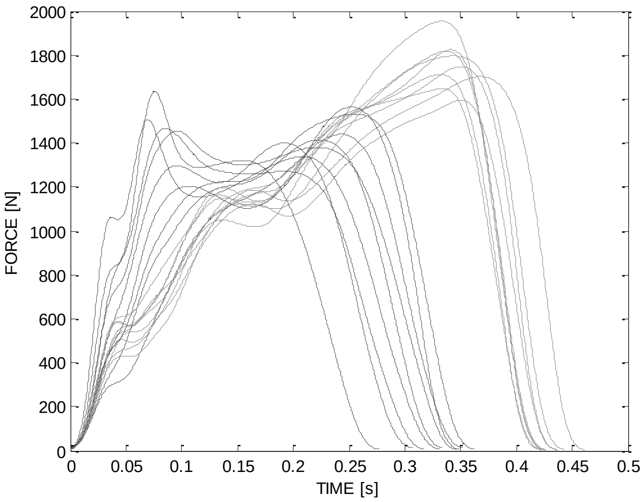

Figure 1: Force-time curves of nine jumps from a goalkeeper (solid lines) and from a non-goalkeeper (dashed lines).

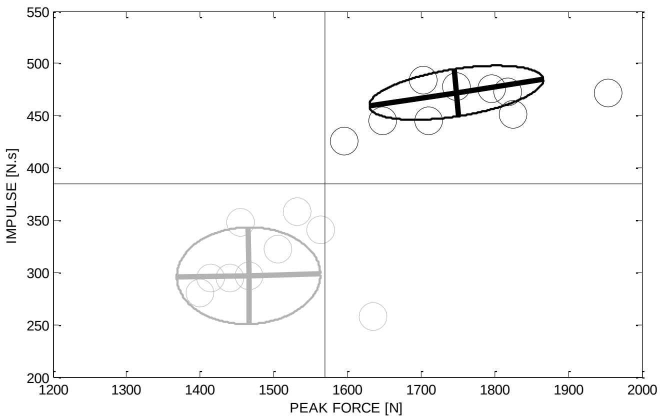

Figure 2: Net force impulse vs. net peak resultant ground reaction force for a goalkeeper (black) and a non-goalkeeper (gray). The ellipses indicate confidence intervals of 95%

The power-time curves of all jumps of a goalkeeper are shown in Figure 3, and they are similar to the force-time curves for the same subject, as one would expect. The correlations between peak force and peak power and between impulse and work were R=0.84 (p=0.0050) and R=0.93 (p=0.0003) respectively. Therefore, the force-time curves can be used to get a good estimate of the power-time properties of a goalkeeper. From the results of this study, it appears that the peak net ground reaction forces and impulses of goalkeepers give a good indication of their jumping ability and performance in reaching a ball thrown to the side and above head height. These variables may be used to assess the jumping ability of a goalkeeper in a real game situation. However, the interpretation of our results is only valid for the jumps executed here (to the side and high) and might not apply to jumping and reaching for a ball that is to the side and low. Also, our results were obtained with no pressure of time as the goalkeepers knew when the ball would be thrown. The results of jumping ability and goalkeeper performance may be altered when time limits are applied in situations where a goalkeeper needs to jump powerfully but also has a limited time to reach the ball. Maximal impulse (with long stance times) may then be compromised to smaller impulses but reduced stance times.

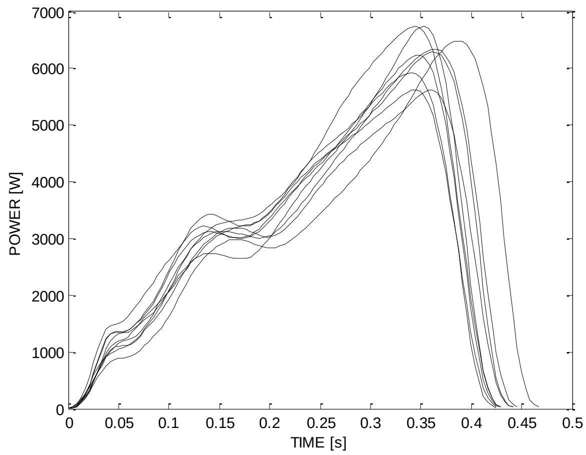

Figure 3: Power-time curves of nine jumps of a goalkeeper**.**

CONCLUSIONS

We conclude that force-time and power-time curves of goalkeepers and non-goalkeepers differ substantially, and that these differences might help identify good goalkeeping and strategies to improve goalkeeping in soccer goalies. Further research will be required to test if the current results also hold for different goalkeeping tasks, a larger group of subjects and for professional goalkeepers.

ACKNOWLEDGEMENTS

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REFERENCES

1. Park SK, Stefanyshyn DJ (2011). Greater Q angle may not be a risk factor of patellofemoral pain syndrome. *Clinical Biomechanics*, 26(4):392-396.