Patellofemoral Joint Compression Forces in Backward Running

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Introduction
Backward running (BR) is used in rehabilitation of patellofemoral pain syndrome (PFPS) patients. It has been reported to have reduced peak patellofemoral joint compression forces (PPFJC) compared to forward running (FR) (1). This may be due to slower speeds of BR. This study investigated: 1) if BR had reduced PPFJC compared to FR at similar speed, and 2) if so, whether this was due to kinematics or kinetics.

Methods
17 healthy volunteers (7 male, 10 female, age: 27±6 years, height: 1.7±0.1 m, mass: 72±20 kg) ran in forward (FR) and backward (BR) direction at a speed of 2.8-3.4 m/s, for three trials each. Kinematics were collected using a VICON system (Oxford Metrics Group Ltd), and ground reaction force data using two force plates (Kistler Instruments Ltd). Kinetics were calculated with VICON and data were further analysed in Matlab (Mathworks Inc). PPFJC was calculated combining experimental data with values for patella tendon moment arm (dPT) and patella mechanism angle from literature (2):

$$PPFJC = \frac{P_{Fg-Fpl}}{F_q}, \text{ with } Q_{Fpl}(F_q) = \frac{M_k}{dPT}$$

with $P_{Fg-Fpl}$: ratio between quadriceps and patella tendon force (extrapolated from (3)); $F_q$: patella tendon force, $Q_{Fpl}$: quadriceps tendon force and $M_k$: peak knee extensor moment. The role of kinematics and kinetics was investigated with a telescopic inverted pendulum (TIP) model. Statistical differences between FR and BR were calculated with an independent t-test (with p<0.001 as significant difference).

Results
Running speed was not significantly different between FR and BR (3.0±0.2 and 3.0±0.2 m/s). PPFJC was significantly higher in FR than in BR (4.5±1.5 and 3.4±1.4 BW). $M_k$ was significantly higher in FR than in BR (158±54 and 124±51 Nm), while knee angle at $M_k$ was not significantly different (44° and 41°). This indicates that kinetics (moments) and not kinematics (knee angle) caused the reduced PPFJC in BR.

TIP model calculations (Fig 1) showed that the stance leg shortened during initial deceleration and extended during push-off in FR and BR. In FR the stance leg extended more during the push-off phase than in BR (Fig 1). In both FR and BR $M_k$ occurred at similar approach angles of the contact leg ($\theta$) (80±4 and 82±3°, Fig 1). The body was upright and leaning forward (as $\theta$ was close to, but smaller than 90°) at $M_k$. $M_k$ therefore resulted in a loading response in both FR and BR, but a push-off response in FR only (a push-off response in BR requires a backward lean, $\theta$>90°). As $M_k$ in BR did not provide push-off, we propose BR seems generated more by pendular movement, while FR has a predominantly telescopic motion (4). Pendular movement does not require high knee extensor moments, but high hip flexor moments to generate push-off. This was confirmed by the significantly higher peak hip flexor moments in BR compared to FR (113±54 and 76±43 Nm).

Interestingly, for some participants (7 in total) PPFJC were similar in BR and FR. This is related to FR style.

Discussion
PPFJC was lower in BR than in FR and this was not due to a difference in speed. The knee angles at the peak knee extensor moment were similar in BR and FR, kinetics differed however with higher peak knee extensor moments in FR and higher peak hip flexor moments in BR. This increased peak knee extensor moment was therefore related to the increased PPFJC in FR. These differences were not consistent in all participants; further research is required to investigate whether it is the BR style that resulted in a reduced PPFJC or whether an adapted FR style could also be advised to PFPS patients in order to exercise with reduced knee pain.

Acknowledgements
This study will also be presented at the ISB 2011 meeting, Brussels, July 3-7.

References

Figure 1: TIP model calculations with stance leg length (L) against $\theta$. The grey lines are average data for BR and the black lines for FR, with the thinner parts for the push-off phase. Stars indicate where $M_k$ occurred. FRPO and BRPO are push-off in FR and BR respectively.