EFFECT OF MENTAL DEMAND ON KNEE FORCES IN PROFESSIONAL YOUTH SOCCER PLAYERS

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Soccer is one of the most popular sports all around the world. It is an injurious type of sport with a focus on lower extremities and high psychological pressure during matches. The stressor is linked with injuries and an increased musculoskeletal loading. This study investigates the influence of cognitive stress on the load profile of the knee joint. Twelve professional youth soccer players performed highly dynamic runs with and without additional cognitive stress. The runs were analysed with a musculoskeletal simulation software. The data analysis shows no difference in knee joint reaction loading under additional mental stress compared to the baseline. Yet running times are significantly lower in the baseline. While there is no increase in the joint loads, the running times indicate an altered movement behaviour when the subjects are exposed to additional mental demand.

KEYWORDS: psychological stress, injury prevention, musculoskeletal simulation

INTRODUCTION: Soccer is one of the most popular sports all around the world. The last FIFA Big Count Survey stated that there are 265 million players in professional and amateur level (FIFA, 2007). At the same time, soccer is an injurious type of sports with a focus on lower extremities. Severe knee injuries are a common problem in soccer (Krutsch et al., 2016) and lead to long absence times (Ekstrand et al., 2011). In relation to total training and play time, most of these injuries occur during matches (Junge et al., 2002), which exert more psychological pressure onto the players (Slimani et al., 2017).
Studies have shown that the risk for sports injuries is linked to psychological symptoms. Anxiety, stress from negative events and daily hassle were identified as indicators (Ivarsson et al., 2013). Additionally, injuries cause higher levels of anxiety leading to a vicious circle (Jansen et al., 2019). The injury risk grows further with an enlarged workload. It has been stated that an increased internal workload over three to four weeks leads to a significantly higher injury risk for professional soccer players (McCall et al., 2018). Psychological stress has also been identified as a cause for higher musculoskeletal loading. Electromyography (EMG) of the upper back muscles showed that muscle activity significantly rises under mental stress and that muscles are active even if there is no physical demand (Lundberg et al., 2002). In another study, the test subjects have been subjected to acoustic stress (Kristiansen et al., 2009) and an increased muscle activity during has been observed. Christou et al. (2004) found fluctuating muscle forces and increased activities under stress in simple tasks. Moreover, Bloemsaat et al. (2005) investigated cognitive tasks in parallel to simple work concerning their effect on muscle activity. Test subjects had to perform simple memory tasks simultaneously to typing on a computer and showed increased musculoskeletal loading compared to typing-only exercise. Marras et al. (2000) examined emotional stress under physical demanding work. They subjected volunteers to negative and positive language while lifting a heavy object and noticed a significant increase in muscle activity and spinal disc loads.
While the muscle activities of the upper extremities as well as the back are widely researched regarding their biomechanical response to psychological stress, only little information is

available for the lower extremities. To the authors' knowledge, there is no research investigating the biomechanical effects of stress on the joint loads of the lower extremities. Therefore, this study investigates the influence of mental demand on the load profile of the knee joint in soccer related, highly dynamic movements.

METHODS: For this study, twelve youth soccer players from a German U17 2. Bundesliga team were recruited. After providing informed consent, the test subjects completed two runs in a SpeedCourt (Globalspeed GmbH, Germany). The SpeedCourt system is a 4x4 m area with twelve integrated pressure sensors and a screen in front. Figure 1 displays a schematic overview of the SpeedCourt. Four sensors are in the middle of the area and function as one combined field in this study. The sensors five to eight are located in the corners and at the sides of the SpeedCourt. The routes were designed as a so-called star run, where the test subjects start in the middle, have to touch a random outer field, return to the middle field and then touch the next random outer field. In one running sequence, each outer field had to be reached two times, resulting in an evenly distributed moving pattern. A screen in front of the court displays the current target field.
The participants performed the first run as baseline without any external stressor and the second one took place with a modified version of the d2-attention test (Brickenkamp et al., 2010) on a second screen in front of the SpeedCourt. This test was selected to generate a standardized, sports-related stress event. For this test, the participants had to recognize the letter *d* with exactly two dashes in an ongoing sequence of *d*'s and *p*'s with a varying number of dashes during the running sequence. After the run, the participants had to complete a self-evaluation form (Hart and Staveland, 1988). They were asked about the perception of mental, physical and timely demand as well as performance, frustration and effort. This assessed the validity of the stressor.

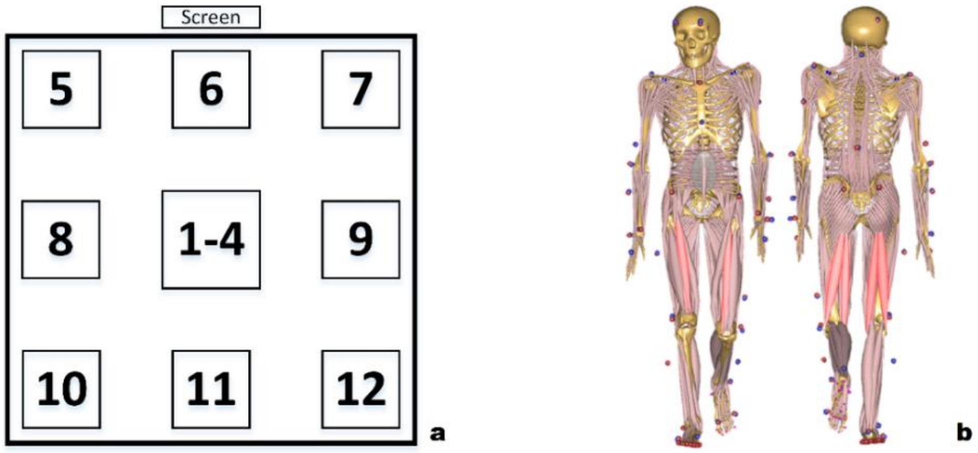

Figure 1: a) Schematic view of the SpeedCourt system with the location and numeration of the pressure sensors. The sensors 1-4 in the middle were treated as one field for this study.
b) Musculoskeletal model of the AnyBody Managed Model Repository (AMMR, v, 2.2.0).

A twelve-camera motion capture setup (Vicon Motion Systems, UK) recorded the participant's kinematics. The motion capture data was filtered using a second order Butterworth filter with an 8 Hz cut-off frequency and served as input for the AnyBody Modeling System (AMS, v. 7.2, AnyBody Technologies, Denmark), an inverse dynamics software. With this software, external forces as well as the musculoskeletal loadings of the human body such as joint reaction forces, muscle forces and muscle activities can be computed (Damsgaard et al., 2006). The applied musculoskeletal model of the software is shown in Figure 1b. A validated method for predicting ground reaction forces was utilized (Skals et al., 2016). Antero-posterior (AP), medio-lateral (ML) and proximo-distal (PD) forces of both knees were determined. For the analysis, only the contact phases of the outer fields were regarded. The contact phase began 0.5 s before foot-to-ground contact and ended 0.5 s after the contact. Because peak loadings are assumed responsible for injuries, only the peak values of the aforementioned parameters were analysed.

For this purpose, the mean peak loading of all participants were investigated. The knee joint reaction forces were normalized to the participants' body weight. For the statistics of the run types, a two-sided Student's t-test with a confidence level of 0.95 was used.

RESULTS: For the baseline as well as for the mental stressor 204 calculations were run. Six computations (one baseline and five stressor) aborted due to numerical errors, resulting in 402 calculations in total. Table 1 shows the mean peak loadings of the parameters for baseline and attention task during the runs. No significant difference is found between the mean baseline and stressor runs ($p>0.05$). The mental demand lead to equally high knee loadings, with no divergent effect for any parameter. While the knee joint reaction forces appear to be slightly higher on the left side, this effect accounts for both the baseline and the stressor.
The mean running times of baseline (35.67±1.75 s) are significantly lower ($p<0.001$) than the stressor times (39.92±3.28 s).
Analysing the self-evaluation forms reveals a significantly increased mental demand for the stressor runs ($p=0.006$). On average, the participants rated the mental demand 28% higher, when exposed to the attention task. Beyond that, physical demand, timely demand, frustration and performance were not rated significantly different for baseline and stressor ($p>0.05$).

Table 1: Mean peak loadings (%BW) and standard deviations of the investigated parameters for the two run types.

	Left AP	Left ML	Left PD	Right AP	Right ML	Right PD
Baseline	693±247	109±61	511±195	659±277	101±48	489±284
Stressor	697±286	106±63	472±155	610±209	94±41	457±141

DISCUSSION: For this investigation of the knee joint loading profile under mental stress twelve professional youth soccer players were tested in highly dynamic motion. On the one hand, the analysis of the mean knee joint loadings shows no difference for the baseline runs and the runs with additional mental demand. On the other hand, the running times are distinctly higher, when the participants are subjected to the attention task. Since the stressor task was rated significantly higher in mental demand with no differences in the other characteristics, the applied attention task can be accepted as a valid mental stressor. These results lead to the conclusion, that the additional mental stress enforces lower running velocities. Although one would expect lower joint reaction forces under stress due to lower speed (Weinhandl et al., 2017), the force level remains the same here. Hence, it can be assumed that higher mental demand leads to increased joint forces. Yet they do not exceed the baseline level due to lower general velocities. Further studies, which take running speed and segment velocities into account, are needed.
This study is subject to some limitations. Since the sequence of fields varies, the movements are not identical. In order to counteract this, the middle field (1-4) acted as neutral base. Moreover, only taking the short contact phases into account as well as every field being touched equally often in each run minimizes the effect of varying field sequence. Furthermore, the musculoskeletal model bears some limitations. Although it has a validated method for predicting ground reaction forces (Skals et al., 2017), the numerical muscle recruitment is only valid for slow or normally fast movements. Hence, the absolute calculated values of the knee joint reaction force may not be accurate. However, the calculated peak values up to 7 BW are comparable to literature data (Lenton et al., 2018) for this exertive motion. Besides, since the same muscle recruitment criterion is applied to both baseline and cognitive stressor runs, the comparison of these remains adequate.

CONCLUSION: The aim of the study was to investigate the effects of mental stress on the knee joint loads in sports-specific movements. The results show unchanged joint reaction forces but an increased running time under higher mental demand. This behaviour should the focus of future work.

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