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Hamstring muscle activation during the flywheel exercises

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ABSTRACT

Aims: Aim of this study was to determine hamstring activation during flywheel (FW) exercises, identify differences between muscles and classify the exercises.

Methods: Exercises were done by professional footballers and electromyography data from hamstring muscles were recorded and normalized according to maximum voluntary isometric contractions (MVIC). Differences between muscles and with-in exercises were compared with repeated measures ANOVA and categorized according to their intensity.

Results: The Exercise variable had significant differences (F(3.1,81.5)=96.5, p<0.05) but the muscles variable F(1,26)=2.24, p>0.05) and Exercise*Muscle interaction effect (F(3.1,81.5)=0.97, p>0.05) were not a significantly different. During Romanian Dead Lift, Single Leg Dead Lift, Leg Curl and Single Leg Hamstring Bridge determined over 80% activation according to MVIC for biceps femoris (BF) and medial hamstring (MH) with not significantly different between each other and they were categorized as high-intensity FW exercises (p>.05). During Bilateral Squat for both musclewere determined below 50% according to MVIC and it was categorized as low-intensity FW exercise. During Single Leg Squat and LUNGE in the MH were below 50% according to MVIC, these exercises were categorized as low-intensity FW exercises and in the BF in the range of 50-80% according to MVIC so they were categorized as medium-intensity FW exercises.

Conclusion: With this study, both parts of the hamstring contract similarly during the selected FW exercises. Low or moderate intensity FW exercises can be used in the early stages of rehabilitation or preventive hamstring exercise programs, while high intensity ones can be used in later processes.

Keywords: Hamstring muscles, eccentric overload exercise, electromyography, iso-inertial technology, football.

INTRODUCTION

The hamstrings are the most frequently injured muscle group in the lower extremity with a prevalence of 30% in athletes who compete, individually or as a team in running-based sports.[1] Biceps femoris (BF) long head is the most frequently injured muscle with 80% rate among hamstring injuries.[2] A decrease in individual or team performance after hamstring injuries and large losses in terms of time and cost and a high rate of repetition direct clinicians and researchers to different studies.[3-5] The flywheel (FW) ergometer has become the preferred equipment by clinicians in preventive rehabilitation programs and also in the process from injury to performance in recent years.[6,7]

The FW ergometer produced by Berg&Tesch researchers in 1994; creates extra load in the eccentric phase of the exercise by converting the moment of inertia generated by the rotating shaft and disk into the opposite force with the appropriate reel, rope and belt during the concentric phase of the exercise.[8,9] In order to complete the FW exercises in coordination with the ergometer, the movements must be done quickly. Speed increases power output and creates high eccentric peak torques of the exercises.[10] The physiotherapists prefer to the FW ergometer during hamstring rehabilitation because of Type II muscle activation and hypertrophy and length-shortening cycles specific to sportive functions during exercises also the ability to realize these effects painlessly and decrease hamstring injury severity and frequency when included in preventive rehabilitation programs.[11-16]

Surface electromyography (SEMG) method is a non-invasive evaluation that provides evidence-based decision making in exercise selection for physiotherapists and sports scientists by detecting and classifying the intensity of electrophysiological changes occurring in the muscles

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during exercises.[17] Commonly used hamstring strengthening exercises, eccentric hamstring exercises, Nordic hamstring exercises, sprinting and exercises are studies in the literature that identify and categorizethe activations occurring in the BF and medial hamstring (MH) contractions. In the literature, there are limited SEMG studiesavailable regarding FW exercises that are only about the leg curl for the hamstring muscles.[18-22]

Our aim in this study in which maximal hamstring activations occurring in 7 different FW exercises were analyzed for the first time, was to determine the BF and MH activation values that occur during exercises, to determine the differences between hamstrings and exercises, to classify exercises according to their intensity. After our studies, we believed that the results could help practitioners to use FW exercises effectively and reliably for post-injury hamstring rehabilitation process or preventive hamstring rehabilitation programs.

METHODS

Ethical Approval

Our research was carried out in the Turkish Super League Team Alanyaspor Club Physiotherapy Department and Indoor Gym. The study started with the permission of Gazi University Ethics Committee (Date: 09/11/2022, Decision No: E-77082166-604.01.02-506690). The individuals participating in the research were informed about the scope and content of the study and their consent was obtained. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Participants

20 male professional football players who have been doing professional team training for at least 4 years, who have not had a hamstring injury in the last 6 months, who have not had any lower extremity surgery before and who regularly continue team training, were identified and the research was started. Before the SEMG measurements two familiarization sessions were made with Desmotec Ergometer System (iso-inertialdevice D Full Line, Desmotec, Biella, Italy) with 0.060 kg.m^2 inertial load, one pro disc (diameter = 0.285 m; mass = 6.0 kg; inertia = 0.060 kg.m^2). Submaximally, the participants were accustomed to the chosen FW exercises and the demographic data recorded, participants' age, body weight, height and dominant extremity were recorded during the famillarization sessions.[15] The dominant side was determined by identifying the leg which he kicks the ball with. On the measurement day a verbal questionnaire with two questions was given to the participants, in which we asked them to evaluate their fatigue and pain out of 10. Six players with knee, groin, ankle and low back pain at a rate of more than 5, were excluded from the study so that the results would not be affected. The study was completed with 14 participants who did not feel any pain.

Exercises

As a result of the literature review, 7 FW exercises were determined that have been used before for lower extremity muscles and or hamstrings ; bilateral squat (BSQ), single leg squat (SLSQ), romanian dead lift ()RDL, single leg dead lift (SLDL), lunge, leg curl (LC) and single leg hamstring bridge were selected (Figure 1.).[15,16,18,23]

Figure 1. Fw Exercises, A1-A2: Procedure of FW BSQ Exercise, B1-B2: Procedure of FW LUNGE Exercise, C1-C2: Procedure of FW SLSQ Exercise, D1-D2: Procedure of FW RDL Exercise, E1-E2: Procedure of FW SLDL Exercise, F1-F2: Procedure of FW LC Exercise, G1-G2: Procedure of FW SLHB Exercise

In order to ensure the standardization of the movements among the footballers during the exercises:

During the FWBSQ the feet were positioned on the flywheel platform at shoulder width and parallel to each other. In order to squat depth, the tape was pulled to give a tactile warning when the femur was parallel to the ground. Verbal warnings were given to prevent medial displacement of the knee joint and to maintain the neutral position of the pelvis (Figure 1., A1-A2).

During the FW lunge exercise, the dominant extremity was placed in the position on the flywheel platform to the front. Verbal instructions were given to move towards the colored cone placed in front of the dominant extremity (Figure 1., B1-B2).

During the FW SLSQ exercise, the dominant side was also positioned on a flywheel platform on one leg. In order to standardize the squat depth, the tape was pulled to give a tactile warning when the knee joint was at the 90 degree angle. Verbal instructions were given to prevent the knee joint from moving medially (Figure 1., C1-C2).

During the FW RDL exercise, the athlete was positioned on the flywheel platform with his feet parallel to each other and at shoulder width. Deadlift depth was determined by measuring with a tape measure from the midpoint of the tuberositas tibia and proximal talus and marking it with a plaster. Exercise limited knee flexion to less than 20 degree angle. Verbal instructions were given to maintain the neural position of the pelvis (Figure 1., D1-D2).

During the FW SLDL exercise, the dominant side was positioned on one leg on the flywheel platform. Deadlift depth was determined by measuring with a tape measure from the midpoint of the tuberositas tibia and proximal talus and marking it with a plaster. The dominant side knee joint was limited to less than 20 degree flexion positions during exercise. The non-dominant leg remained neutral as the body moved forward. Verbal instructions were given to maintain the neural position of the pelvis(Figure 1., E1-E2).

Before starting the LC exercise, the portable treatment table was positioned in front of the Desmotech device. While the athlete was in the prone position, his pelvis was fixed to the bed with the Mulligian belt. The flywheel rope was attached to the dominant side extremity at the ankle with the wrist belt. Verbal instructions were given to pull the heel towards the hip (Figure 1., F1-F2).

Before starting the SLHB exercise, 60 cm high boxes were placed on both sides of the desmotech device. After positioning the dominant side extremity heel on one boxing and the upper back on the other boxing, the desmotech rope was fixed to the athlete with a waist belt. Verbal instructions were given until the knee, hip joint, and shoulder were in the same direction (Figure 1., G1-G2).

SEMG Measurement

During the 7 flywheel exercises of the participants, hamstring activations were measured with a 6-channel FreeEMG 100 RT model SEMG device of BTS bioengineering company, which can record at 1000 Hz sampling rate. SEMG data was collected from the dominant side. Before the measurements, each player warmed up with a standard 10-minute 3rd level resistance 90 revolutions per minute (RPM) cycling (Indoor Exercise Bike, Technogym, Italy) and stretching program. After warming up, disposable, self-adhesive Ag/AgCl electrodes (Noraxon Dual EMG Electrode, U.S.A) with a diameter of 10 mm were attached on the skin after cleaning with a disposable razor blade and alcohol. EMG electrodes were attached to the dominant extremity parallel to the projection of the hamstring, the distance between the tuber ischiadicum and the tibia epicondyluslateralis and medialis was measured with a tape measure and attached to the midpoint of it with a distance of 20mm between them according to SENIAM guidelines.[24]

Maximum Volunteer Isometric Contraction (MVIC)

For MVIC, it was repeated 3 times in prone 45 degree knee flexion position. Each isometric contraction continued for 5 seconds, and a 30-second rest period was given between contractions.18 After the MVIC, the athletes were given a recovery time of 10 minutes.

Exercise Protocol

10 repetitions of FW exercises were performed with full effort for both extremities. At the same time participants were followed by an experienced physiotherapist with clear and loud verbal encouragements like ‘as much as faster as you can’. The exercises were applied to all the athletes in the same order,to fix the rope of the flywheel device to the football players different equipment was required (desmotech vest, desmotech belt, short hand bar) and also (treatment bed, mulligan belt, 60 cm boxes) was required for some exercises. In order not to waste time randomization could not be done during the exercises. The exercises using the same equipment were done one after the other.

With a rest period of 5 minutes between the exercises.[18]

Another physiotherapist who had experiences about SEMG measurements, followed and recorded the raw SEMG data from hamstrings during FW exercises.

SEMG Data Analysis

First, the recorded raw EMG signals during the FW exercises and MVIC contractions were passed through a 20 Hz IIR Butterworth High Pass and 450 Hz IIR Butterworth Low Pass motion artifact and ECG filter. Root Mean Square (RMS) values were calculated from consecutive 0.1 s time windows from the filtered EMG signals.

The average of 3 peak EMGrms signal amplitudes observed during 5 sec MVICs were used as a reference.[18]

During each FW exercise, the average of 3 peak EMGrms signal amplitude was determined and divided by the reference value and normalization operations were applied.[25]

The normalised values below 50% had been categorized as low-intensity, those with a range of 50-80% had been categorized as medium-intensity and above the 80% had been categorized as high-intensity FW exercises for hamstrings.[18]

Statistical Analysis

Statistical analysis of the study was performed using the ‘Statistical Package for Social Sciences’ (SPSS) Version 22.0 (SPSS inc., Chicago, IL, USA) program. The normal distribution of the data was determined using visual (histogram and probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk Test, Skewness/ Kurtosis). Data was examined with Two Way ANOVAin the repeated measurements. Muscles were determined asan independent variable (between factor); and EMG data occurring in Exercises was determined as a dependent variable (with in factor).[21] Bonferroni’s correction was used to reduce the margin of error for exercises pairwise comparisionsand the p value was accepted as 0.05.

RESULTS

Participants

18-30 age range with a median age of 18.5 years of the 14 participants other demographic data was summarized in the Table 1.

Table 1. Demographic datas.

	X±Sd	Min.	Max.
Height (cm)	180±7	169	193
Weight (kg)	73±7	60	89
Dominant side (player)	6 (left)	8 (right)	

*X: mean value, Sd: standart deviation, Min.: minimum value, Max.:Maksimum value.

BetweenMuscleand with-in ExerciseDifference

According to the Two Way ANOVA in the repeated measurements test results, it was seen that the Exercise variablehad significant differences($F(3.1,81.5)=96.5$, $p<0.05$) but the Muscle ($F(1,26)=2.24$, $p>0.05$) and Exercise*Muscle interaction effect ($F(3.1,81.5)=0.97$, $p>0.05$) were not significantly different. In other words, when footballers work on the FW ergometer with full effort LH and MH muscles contract similarly, although there were differences between exercises.

Peak Muscle Activity

In all 7 FW exercises, muscle activation determined in BF muscles was higher than in MH muscles, but the activation difference was not significantly different ($p>0.05$) (Figure 2).

The highest muscle activation for BF and MH occurred in FW LC exercise ($p>0.05$) (Figure 2).

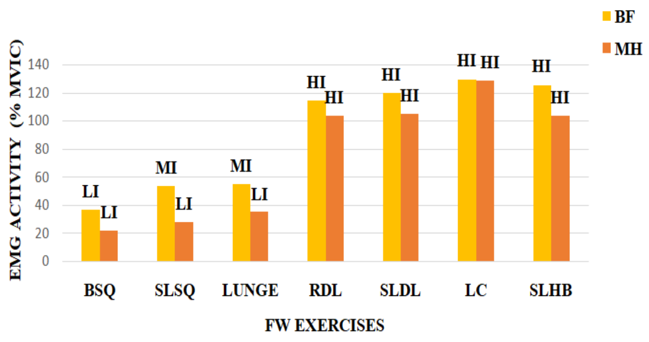

Figure 2. Hamstring EMG activity. *Bilateral squat: BSQ, Single leg squat: SLSQ, Romanian deadlift: RDL, Single leg deadlift: SLDL, LUNGE, Leg curl: LC ve Single leg hamstring bridge: SLHB.
*Biceps femoris: BF, medial hamstring: MH.
*HI: High intensity, MI: Moderate intensity, LI: Lowintensity.

The lowest muscle activation for both BF and MH occurred in the FW BSQ exercise (p>0.05) (Figure 2).

Pairwise Comparisons of FW Exercises

The maximal activation values measured in BF and MH muscles during FW exercise are as summarized in (Table 2).

There are significant activation values differences between during the FW RDL, SLDL, LC and SLHB exercises and the BSQ, SLSQ and LUNGE exercises (p<0.05) (Table 2).

During FW; RDL, SLDL, LC and SLHB exercises activation values were determined over 80% compared to MVIC for both BF and MH muscles and not significantly different between them and they were categorized as high-intensity FW exercises for both muscle groups (p>0.05) (Table 2).

During the BSQ, SLSQ and LUNGE exercises in the MH muscle, the maximal activation values were determined and were not significantly different between them and below 50% compared to the MVIC, these exercises were categorized as low-intensity FW exercises for the MH muscles (p>0.05) (Table 2).

During the LUNGE and SLSQ exercises in the BF muscle, the maximal activation values were used in the range of 50-80% according to the MVIC and were categorized as medium-intensity FW exercises. During BSQ exercise in the BF muscle, the activation value was determined below 50% according to MVIC and it was categorized as low-intensity FW exercise. There was not a significant difference between the values determined during the BSQ, SLSQ and LUNGE exercises for the BF muscle (p>0.05) (Table 2).

DISCUSSION

The main purpose of this study was to determine the maximal muscle activations in 7 different FW exercises and the differences between hamstring muscles and to be able to make evidence-based FW exercise selection in clinical decision making. In this study, which was conducted for the first time in the literature, BF activation was higher than MH activation in all 7 FW exercisesperformed by 14 professional football players, but the difference was notstatistically significant. FW RDL; SLDL; LC and in SLHB exercises, over 100% activation occurred in both muscle groups compared to MVIC, but the differences between exercises were not significantly different. FW BSQ; SLSQ and in LUNGE exercises, activation occurred in both muscle groups below 60% compared to MVIC, but the activation differences in the muscles in these exercises were not significantly different. In the literature; the average activation that occurs during the exercises according to the MVIC for hamstrings was categorized as low intensity exercises that are below 50%, medium intensity exercises in the range of 50-80%, high intensity exercises that are above 80%.[18] According to this categorization method, FW RDL, SLDL, LC, SLHB exercises were high-intensity for both muscle group; FW BSQ exercise was low-intensity for both muscle groups; FW LUNGE and SLSQ exercises were low-intensity for MH muscles, but medium intensity for BF muscles. There were significant differences between FW exercises that produce high-intensity activation for hamstrings and FW exercises that create medium or low-intensity activation for hamstrings.

Although the rehabilitation process varies depending on the size and location of the hamstring injury, eccentric exercise loads progress from low intensity exercises in the first weeks to medium and high intensity exercises in the following week or from bilateral close-kinetic-chain-exercises (CKCE) such as BSQ, RDL, LUNGE to open-kinetic-chain-exercise (OKCE) such as LC.[26,27] If we interpret our study results together with that knowledge, we thought that bilateral CKCE such as FW BSQ, LUNGE, where hamstring activation was moderate or low intensity could be used after early period ofpostinjury rehabilitation and unilateral CKCE such as FW SLSQ could be more suitable for optimal loading in the following process. At the beginning of the remodeling phases, high-intensity CKCE exercises that bilateral FW RDL or unilateral FW SLDL, SLHB not significantly different each other could be used. The FW LC exercise, which is a high-intensity OKCE, could be used in functional rehabilitation or return to sports phases.

There were also studies in the literature show that weekly regular FW exercises within the scope of preventive rehabilitation reduce hamstring injuries. Askling et al.[16] in 2003 published a controlled study in that 10-week FW LC exercise performed within the scope of preventive rehabilitation in addition to the routine team training showed decreases in hamstring injury severity and frequency. According to a controlled study published by de Hoyo et al.[14] in 2015 ,showed that football players who performed 10-week FW LC and FW BSQ exercises performed as part of preventive rehabilitation in addition to routine team training showed decrease in the frequency of hamstring injuries per 1000 hours of training and/or game time. When this information was synthesized with the results of our study, we think that

Table 2. Hamstrings % values according to MVIC.

	BSQa	SLSQa	LUNGEa	RDLb	SLDLb	LCb	SLHBb
BF	36±34	53±32	55±35	114±52	120±42	129±29	125±35
MH	22±16	27±17	35±23	103±57	104±33	129±27	103±24

*all values mean % MVIC ± SD, *Bilateral squat; BSQ, Single leg squat; SLSQ, Romanian dead lift; RDL, Single leg dead lift; SLDL, LUNGE, Leg curl; LC ve Single leg hamstring bridge; SLHB, *Biceps femoris; BF, medial hamstring; MH, *a not significantly different between exercises for BF and MH, p>05, b not significantly different between exercises for BF and MH, p>05, a and b significant differences between exercises for BF and MH, p<05.

there was a potential to reduce the severity and frequency of hamstring injuries by creating permanent chronic adaptations as a result of long-term training, especially due to the FW LC exercise, which created the highest EMG activation. In addition, we think that the FW SLDL, RDL or SLHB exercises, which created high-intensity activations for BF and MH which were similar to FW LC exercises in our study and may cause chronic adaptations in the hamstrings when they are included in the weekly training program.

There were some studies where the Nordic exercise which was the most commonly used eccentric hamstring exercise and FW exercises were compared.[28] Timmins and his colleagues divided a football team into two groups, one group performed the Nordic hamstring exercise and the other group performed the FW BDL exercise for preventive rehabilitation purposes during the season. In repeated measurements at the end of the season, significant changes in the length of the athletes' BF fiber in both groups compared to the pre-season were measured, and the difference between the groups were not significant.[29] The SEMG study, in which they compared the hamstring activation that occurred in football players during the Nordic hamstring exercise and FW LC exercise, the activation values in the hamstring muscles during the exercises were found to be equal for the eccentric phase and higher in the FW ergometer than Nordic exercise for the concentric phase. Therefore, they interpreted the results of the study as using the FW LC exercise can be an alternative to the Nordic exercise.[22] These results also support our view that high-intensity FW exercises for hamstring muscles, such as RDL and LC, could cause chronic adaptations.

Research about FW ergometer that had high levels of evidence; Meta-analyse, systematic reviewand randomized controlled trial had a consensus that it can be used for an eccentric overload training.[30-32] FW LC, RDL, SLDL and SLHB exercises, in which we determined high-intensity SEMG activation with 0.06kg.m^2 inertial load in the hamstring muscles in our study and can be used during the return to running, playing or sports phases of rehabilitation for reduce the strength difference between the extremities. In addition, we anticipated that it could be used for preventive rehabilitation purposes in order to minimize the risks determined as a result of advanced analyses such as extremity symmetry index, functional hamstring quadriceps ratio. Although different studies need to be done about these views, we think that our study results will help clinicians in choosing flywheel exercises to protect against hamstring injuries.

Limitation

Although we commanded the exercises to be done as fast as possible, the fact that no method was used to measure the movement speed was a limitation of our study.

CONCLUSION

With this study, both parts of the hamstring contract similarly during the selected FW exercises. Low or moderate intensity FW exercises can be used in the early stages of rehabilitation or preventive hamstring exercise program, while high intensity ones can be used in later processes.

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ETHICAL DECLARATION

Ethics Committee Approval: The study was carried out with the permission of Ethical Committe of Gazi University. (Date: 09/11/2022, Decision No: E-77082166-604.01.02-506690).

Informed Consent: All patients signed and free and informed consent form.

Reviewer Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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