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ORIGINAL ARTICLE

Measurement of electromyography during bobsleigh push-start: A comparison with world top-ranked athletes

Mesure de l'activité électrique musculaire pendant la poussée de Bobsleigh : comparaison avec les athlètes de niveau mondial

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Summary
Aims. — In the present study, we aimed to determine the muscles that mostly respond to the push-start of the sled.
Methods. — Seven male Korea Winter Olympics elite athletes form the two-man bobsleigh team. Performance was assessed using push-start time. Electromyogram (EMG) activity of the rectus femoris (RF), tibialis anterior (TA), gastrocnemius medialis (GM), and biceps femoris (BF) muscles was recorded during the push-start phases.
Results. — The paired *t*-test showed that right and left GM activity ($P < 0.001$) was significantly higher in top-ranked athletes than ordinary athletes. However, no significant difference in EMG activities of the RF, TA, and BF was observed, but there was a trend toward higher BF (left) activity ($P = 0.066$) in top-ranked athletes. Stepwise multiple regression revealed that the left (multiple $r^2 = 0.081$; $P < 0.01$) and right BF (multiple $r^2 = 0.078$; $P < 0.01$) were a significant and powerful predictor that accounted for 8.1% and 7.8% of the variance in start time, respectively.
Conclusion. — This study provides preliminary evidence to suggest that BF muscle activity may represent an effective push-start time to reduce race time in bobsleigh athletes.

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Résumé
Objectifs. — Dans cette étude, nous avons cherché à déterminer quels muscles étaient le plus sollicités au départ, au cours de la poussée du bobsleigh.
Méthodes. — Sept athlètes coréens d'élite olympique d'hiver, membres de l'équipe de bobsleigh à deux ont été testés. Leur performance a été évaluée en utilisant le temps de démarrage. L'électromyogramme (EMG) des muscles droit antérieur (RF), tibial antérieur (TA), gastrocnémien médian (GM) et biceps fémoral (BF) a été enregistré pendant les phases de poussée.
Résultats. — Le test *t* apparié a montré que les signaux EMG du GM droit et gauche ($p < 0{,}001$) étaient significativement plus élevés chez les athlètes de haut niveau que chez les athlètes de niveau inférieur. Cependant, aucune différence significative n'a été retrouvée pour les signaux EMG des muscles RF, TA et BF; seule une tendance pour une activité EMG plus élevée dans le muscle BF gauche ($p = 0{,}066$) chez les athlètes les mieux classés, comparativement aux sportifs de niveau inférieur. La régression multiple pas à pas a permis de suggérer que les activités EMG des muscles BF gauche (multiple $r^2 = 0{,}081$; $p < 0{,}01$), et BF droit (multiple $r^2 = 0{,}078$; $p < 0{,}01$), étaient des prédicteurs significatifs et puissants qui représentait 8,1 % et 7,8 % de la variance de la performance (temps de mis pendant la poussée initiale).
Conclusion. — Cette étude fournit des éléments préliminaires suggérant que l'activité musculaire du BF pourrait être associée à un bon départ en bobsleigh, ce qui est un facteur de performance pour le reste de la descente.

1. Introduction

Bobsleigh is one of the fastest Winter Olympics sports, and world championships are held annually. Push-start is very important for bobsleigh athletes because the race is over in 1~2 min at a speed of 130 to 140 km/h [1]. A standard bobsleigh push-start is divided into three main stages: start run, drive, and finish [2]. In the start stage, the athletes have to start the race by pushing the sled within 60 s of the start signal and running at full speed by pushing the sled about 55 m. The start and running stages end within 6 s; however, these stages have the greatest contribution on the race performance [3].

The normal and abnormal muscle activation can be assessed using the electromyogram (EMG), and amplitude of EMG reflects the recruitment and discharge rates of the active motor units and serves as an index of neuromuscular function [4]. Many sport scientists are using an EMG spectrum recorded during a dynamic sports movement which yields its own information obtained by EMG spectra recorded for isometric contraction or muscle biopsies [5].

Previous studies reported that hamstring EMG activities were measured during maximal contractions and exercise repetitions in soccer players to provide practical settings in which this exercise is now prescribed before sport-specific training sessions [6]. Howard et al. [7] showed that the biceps femoris (BF) plays an important role in the glide technique, with the total duration of high volumes of activity between 34 and 53% of the throw cycle, in an EMG analysis of the muscle activity of the legs during shot put in 15 national-level shot putters. Zebis et al. [8] reported that EMG activity of the hamstring and quadriceps muscles was significantly increased by the injury prevention program in handball and football players with anterior cruciate ligament injuries.

Therefore, finding the key muscles that are most active during exercise or first exhausted is an important element of training planning and improving performance [9]. In the present study, we aimed to determine the muscles that mostly respond when start pushing the sled. This was done by comparing the EMG activity between the world top-ranked athletes and ordinary athletes in the Winter Olympics and analyzing changes of the EMG signals during each test.

2. Materials and methods

2.1. Participants

Seven male Korea Winter Olympics elite athletes form a two-man bobsleigh team (Table 1). In this study, five ordinary athletes were defined as within the top 30 in the International Bobsleigh and Skeleton Federation (IBSF) ranking list. Two of the athletes were ranked No. 1 in the IBSF ranking list in the 2015/2016 session. The exclusion criteria for the subjects are as follows:

- history of bony or soft tissue lower limb surgery;
- musculoskeletal disorders;
- any medical treatment.

All subjects who agreed to participate in the study had the study explained to them to ensure a complete understanding of its purpose and methods, in accordance with the ethical principles of the Declaration of Helsinki. The subjects also signed an informed consent form before participation.

2.2. Measurements of body composition

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, using an InBody 370 body composition analyzer (InBody Co. Ltd, Seoul, Korea). BMI was calculated as weight (kg) divided by height squared (m^2).

Table 1 The characteristic of the subjects.

Variable	World-class ($n = 2$)	Ordinary athletes ($n = 5$)	*P*-value
Age (years)	30.00 (4.24)	28.20 (1.92)	0.439
Height (cm)	181.4 (1.56)	180.7 (3.95)	0.826
Weight (kg)	99.35 (7.14)	93.72 (5.90)	0.325
BMI (kg/m^2)	24.40 (0.42)	24.28 (1.17)	0.898
%BF (%)	19.05 (2.90)	16.26 (1.85)	0.173
LBM (kg)	80.35 (2.90)	78.50 (5.27)	0.670
Career (years)	7.00 (0.00)	6.20 (1.64)	0.544

Values are mean (SD). BMI: body mass index; %BF: percent body fat; LBM: lean body mass.

2.3. Electromyogram measurement

After determining the characteristics of each individual, EMG recording was conducted during push-start on the start slope. Before electrode application, the skin of all athletes was carefully cleaned with alcohol and shaved for high-quality EMG acquisition. Surface EMG signals were detected from the muscles of the right and left legs in which bilateral bipolar Ag/AgCl surface electrodes (conducting surface diameter, 14 mm; distance from the center of the two electrodes, 15 mm; Noraxon Dual Electrodes, Noraxon, Scottsdale, USA) were placed on the rectus femoris (RF), tibialis anterior (TA), gastrocnemius medialis (GM), and BF. Electrode placement is determined under the guidance of the recommendations for the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) [10].

2.4. Data collections

The EMG signals were bandpass-filtered between 20 Hz and 350 Hz and then digitized at a sampling rate of 1000 Hz. In the normalized, rectified, and smoothed EMG, the dependent variables studied were the onset and offset muscle activation time and EMG root mean square (RMS) between onset and offset of muscle activity, and the time of peak EMG was measured and analyzed. To normalize EMG data of the lower limb muscles, reference voluntary contraction (RVC) data were collected when athletes were in the push-start phases. The RVC maneuver was repeated three times, and the mean value of the average muscle activity for the three trials was used to normalize lower limb muscle activity. The root mean square values were calculated and normalized to the RVC value and are presented as percentage (%RVC). The formula for %RVC is as follows:

$$\%RVC = [\text{averageRMSEMG}/\text{RVC}] \times 100$$

2.5. Statistical analysis

The SPSS version 19.0 for Windows (SPSS, Inc., Chicago, IL, USA) was used to perform all statistical evaluations. Body composition was further analyzed for significant difference between the groups using a one-way Anova. A paired *t*-test was used to calculate the statistical significance of the EMG activities of the top-ranked and ordinary athletes. Moreover, stepwise multiple regression analysis was used to examine the relationships between performance level and EMG activity. The coefficient of determination r^2 was calculated for the regression equations. r^2 represents the percentage of variance by the independent variables to predict a dependent variable. The relationships among variables were analyzed using Pearson's correlation coefficients. Statistical significance was accepted at the 0.05 level. All variables are presented as means and standard deviations.

3. Results

3.1. EMG activity according to performance level

The EMG activity according to performance level is shown in Fig. 1. Paired *t*-test showed that right and left GM ($P < 0.001$)

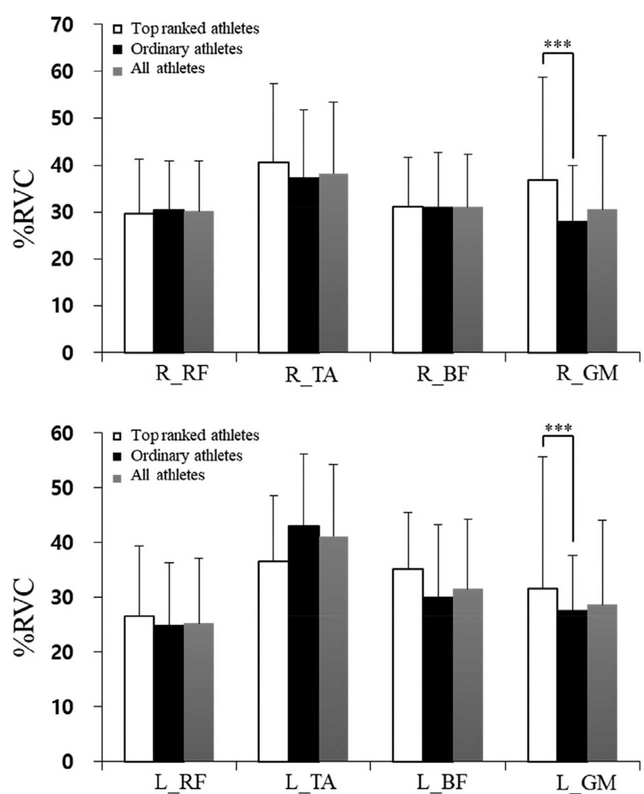

Figure 1 Electromyogram (EMG) activity according to performance level. R_RF; right rectus femoris; R_TA; right tibialis anterior; R_BF; right biceps femoris; R_GM; right gastrocnemius medialis; L_RF; left rectus femoris; L_TA; left tibialis anterior; L_BF; left biceps femoris; L_GM; left gastrocnemius medialis. *: calculated by paired *t*-test, *** $P < 0.001$.

Table 2 Pearson's correlation coefficients among the EMG activity.

	S_T	R_RF	R_TA	R_BF	R_GM	L_RF	L_TA	L_BF	L_GM
S_T	1								
R_RF	−0.172	1							
R_TA	−0.025	−0.157	1						
R_BF	−0.128	0.119	0.110	1					
R_GM	−0.046	−0.099	−0.370**	0.030	1				
L_RF	−0.011	−0.112	0.580**	0.034	−0.368**	1			
L_TA	−0.176	0.289**	−0.453**	−0.037	0.575**	−0.458**	1		
L_BF	−0.285**	0.159	0.027	−0.433**	−0.089	0.102	0.121	1	
L_GM	0.039	0.094	0.726**	0.013	−0.606**	0.522**	−0.471**	0.168	1

Pearson's correlation coefficient was employed to determine the relationship among parameters.
EMG: electromyogram; S_T; start time; R_RF; right rectus femoris; R_TA; right tibialis anterior; R_BF; right biceps femoris; R_GM; right gastrocnemius medialis; L_RF; left rectus femoris; L_TA; left tibialis anterior; L_BF; left biceps femoris; L_GM; left gastrocnemius medialis.
** $P < 0.01$.

was significantly higher in top-ranked athletes more than ordinary athletes. However, no significant difference in RF, TA, and BF, but the trend toward higher BF (left) ($P = 0.066$) in top-ranked athletes.

3.2. EMG activity influence to reducing race time

Table 2 shows the correlation coefficients of among the EMG activity. Negative correlation was found between start time and left BF. Moreover, negative correlations were found between right TA and left TA, right BF and left, and right GM and left GM. Moreover, positive correlations were found between RF and TA, as well as TA and GM (each opposite side).

Table 3 shows the stepwise multiple regression revealed that left biceps femoris, Multiple $r^2 = 0.081$; $P < 0.01$, right biceps femoris, Multiple $r^2 = 0.078$; $P < 0.01$, were a significant and powerful predictor that accounted for 8.1% and 7.8% of the variance in start time.

4. Discussion

The present study is the first of its kind to compare the EMG activities between the world top-ranked athletes and ordinary athletes in the Korea Winter Olympics. The main finding of the study was the presence of BF (right and left) muscle activation might reduce the time during a race.

The gravity-dependent load of the human body, acting on the lower limbs in the upright position, seems fundamental to the maintenance of lower limb skeletal muscle function [11]. The lower limb muscles have a high level of workload while running, so muscle strength is an important factor in achieving fast movement during the race or performance [12]. The importance of push-start times on bobsleigh performance means that the athletes should exert great strength to move the sled from the start [13]. Bobsleigh push-start motion is very similar to the acceleration phase of sprinting. Previous studies that reported on the EMG activity of sprinters in the acceleration phase have revealed that the BF (hamstring muscle) is one of the most important muscles in developing maximal speed [14]. In the present study, the BF activity (left, $r^2 = 0.081$, $P < 0.01$; and right, $r^2 = 0.078$, $P < 0.01$) and start time had a significant influence on reducing the race time in the multiple regression analysis. In addition, this result suggests that the push-start time of top-ranked athletes and ordinary athletes had a 16% difference. In contrast, increasing BF activity might reduce push-start time. Thus, left and right BF muscle activation might reduce the time during a race.

The main muscles of the support limb are the BF, semitendinosus, RF, vastus lateralis, TA, GM, and soleus [15]. In this study, the RF, TA, GM, and BF were analyzed. Because the analysis of the temporal pattern of individual muscles that focuses on the assessment of sprint. The activity of the RF muscles begins just before the foot strikes; however, the BF muscles are not active during the early swing phase, but in the late swing phase, they decelerate hip flexion, followed by controlling knee extension [16]. This study showed that positive correlations were found between the RF and TA and also TA and GM activities (each opposite side). Moreover, negative correlations were found between the right and left TA, right and left BF, and right and left GM activities. These results are supported by several studies, which

Table 3 Multiple regression analysis of race time and EMG activity.

Variable	R	r^2	β	F	*P*-value
Right biceps femoris	0.081	0.081	−0.420	7.271	0.009
Left biceps femoris	0.159	0.078	−0.310	7.674	0.001

EMG: electromyogram.

reported that increased lower limb muscle co-activation could, therefore, compensate for the weakness of the lower limb muscles, increasing stability in the stance and running [17,18].

Surface EMG (sEMG) has been used in both research and clinical applications for noninvasive neuromuscular assessment in several different fields such as sport science, neurophysiology, and rehabilitation [19]. An EMG amplitude has a significant correlation with the level of activation and muscle strength [20]. Furthermore, EMG power spectrum has been shown to be positively correlated with peak torque [21]. Hansen et al. [22] reported that significantly different levels of normalized EMG activity increasing with load were observed between the different loading conditions for healthy controls. Liebenberg et al. [23] also reported that, using the average and root mean square EMG as parameters, the muscle activity (BF, RF, TA, and GM) decreased as body weight decreased. In this study, there was no significant difference between the groups. However, a significant higher GM activity (right and left) ($P < 0.001$) as well as a trend toward higher BF activity (left) ($P = 0.066$) in top-ranked athletes was observed. Thus, we predicted that the muscle activity of top-ranked athletes in the running mechanism was higher than that of ordinary athletes.

The present study has some limitations and points to suggest for further research. We did not consider conducting single muscle fiber analyses for fiber type distribution [myosin heavy chain (MHC)], fiber size, contractile function (strength, speed, and power), and mRNA expression. However, single muscle fiber analyses should be considered in future studies. Another limitation is that the small number of subjects included could limit the statistical power of the result, and further studies with larger populations are required to validate our findings.

5. Conclusions

We provided a description of the importance of push-start in bobsleigh as several studies reported that bobsleigh is considered a speed-strength-power event as down time (finish time) is highly correlated to start time [24]. Our data indicates that BF muscle activity may represent an effective push-start time to reduce race time in bobsleigh athletes. We showed that bobsleigh athletes should focus training for strength and stabilization of the BF among the muscles of the lower limbs. Therefore, these findings provide preliminary evidence indicating that an increased activity of the BF by training will improve injury prevention and performance of bobsleigh athletes. Moreover, coaching staffs, trainers, and sports scientists are the focus of the improvement, making a stabilization and strength training program for the BF in bobsleigh athletes.

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Disclosure of interest

The authors declare that they have no competing interest.

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