A Pilot Study on Electromyographic Analysis of Single and Double Revolution Jumps in Figure Skating

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Abstract

The purpose of this study was to examine the muscle activation patterns during the take off and landing phases of single and double revolution jumps in figure skating. One professional male figure skater performed the following jumps: a single and double toe-loop and; a single and double flip. Using electromyography (EMG) the integrated rectified value (iEMG) was calculated for the following muscles of the take off and landing legs: gastrocnemius medialis, rectus femoris, biceps femoris and adductors. For the take off phase all values were clearly higher in the double revolution jumps for all muscles, while a similar pattern in the landing phase was observed for the adductors only. The activation of each muscle varied with the type of jump and the number of revolutions, suggesting that figure skaters might alter the muscles' EMG activity and, thus, the technique of the jump according to the number of revolutions required.

Keywords: EMG, muscle activation, rotations, skater

Introduction

Figure skating is one of the most complex and intense sports, with the vast amounts of movements made on the ice including among others spins, lifts and more importantly, jumps. Nowadays, competitive figure skaters of an international standard are able to complete up to four rotations within one jump. The successful performance of figure skating jumps is achieved with a combination of several factors, with vertical velocity at take off being one of the main factors identified in previous studies *(King, 2005). King (2005)* stated that despite that vertical velocity at take off appears to be similar among different revolution jumps, when comparing skaters of different abilities, those with higher abilities generate greater vertical velocities at take off for the same type of jump. King suggested that the primary factor in generating vertical velocity is the powerful extension of the legs, implying that the contribution and activation of the lower extremity muscle groups plays a vital role in successful jump performance. Electromyography (EMG) can be a useful tool for the examination of the contribution of different muscle groups during figure skating jumps. However, muscle activation patterns of the lower extremities have not been studied in figure skating.

The execution of a figure skating routine during competition includes a combination of different jumps, with take off from both the dominant (DL) and non-dominant leg (NDL), and the number of rotations in the air varying from one to four. As one would expect, research has shown that the individual jump technique differs according to the number of rotations performed. For example, *King et al. (2004)* reported differences between three- and four-revolution jumps in a number of kinematic variables measured and for both the take off and landing phases. Given the lack of data with regard to muscle activation patterns for the latter phases and for both the DL and NDL, an EMG analysis of muscles groups of the lower extremity in figure skating jumps would be informative with respect to identifying individual muscle differences in activation patterns between jumps with different number of rotations, as well as the relative contribution of different muscle groups when performing the jumps.

The purpose of the present study was to measure the EMG activity of the main muscle groups of the lower extremity during the take off and landing for one- and two-revolution figure skating jumps, which require take off from both the DL and NDL.

It was hypothesised that the EMG activity would be greater for the two-revolution jumps.

Material & Methods

Participants

One male professional figure skater (age: 28.6 years; body mass: 78.6 kg; height: 180.3 cm) participated in this study. The participant had obtained National Ice Skating Association qualifications and had over 15 years experience in professional figure skating. The testing procedures were approved by the institutional ethics committee and the participant signed an informed consent form before tested.

Selection of figure skating jumps and muscle groups

The ‘toe-loop’ and the ‘flip’ jumps were selected. The toe-loop is a jump with a take off from the inside edge of one skate, followed by one or more full rotations in the air, and a landing on the back outside edge of the opposite skate. The flip is a jump with a take off from the outside edge of one skate, followed by one or more full rotations in the air, and a landing on the back outside edge of the same skate. These jumps were selected on the basis that they are simple jumps that are commonly used in figure skating, they are being taught from beginner to advanced level skaters, they can be performed with up to a maximum of four rotations and they require take off from different legs.

Despite the lack of studies in figure skating jumps, the EMG activity of lower extremity muscle groups has been studied for a variety of vertical jumps performed under several conditions and on different surfaces. It has been suggested that the gastrocnemius medialis (GM), the rectus femoris (RF), the biceps femoris (BF) and the adductors (AD) are some of the main muscle groups activated when jumping *(Nagano et al., 2005; Zajac, 2002)*. Thus, these muscle groups were selected for the EMG analysis of this study.

Testing procedure and EMG recordings

Before the test, the muscle bodies of the participant’s muscles were identified, shaved and cleaned with alcoholic sterile wipes. Noraxon bipolar passive surface electrodes (Ag-Ag-Cl, diameter 1.0 cm, inter-electrode distance: 2.0 cm) were placed over the GM, RF, BF and AD of both legs. The reference electrode was placed on the anterior bony side of the knee. All electrodes were safely attached on the participant and any loose wires were securely taped to the legs and protected by the skater's clothing. The electrode placement was checked by movements such as vertical jumps and squats and by manual palpation.

The skater did a personalised warm-up which also included toe loop and flip jumps. Then, for both the toe loop and the flip, the skater performed three jumps with a single and three jumps with a double rotation in the air before landing. For each jump variation the mean values of the three trials were used for the subsequent analyses. The toe-loop required take off from the NDL and the flip from the DL, while the skater landed on the DL in both jumps. For the analysis of the present study, the take off phase was defined as the period between the touch down and the take off of the take off leg before projecting the skater's body in the air. The landing phase was defined as the period between the touch down (following the rotations in the air) and the point of maximum knee flexion of the landing leg. For the identification of these phases, and in addition to the EMG analysis described below, two video cameras (Sony DCR-VX1000E, 50Hz frequency) were fixed on tripods and recorded simultaneously the jumps from the frontal and sagittal plane (90° angle). The space for the jumps was marked and calibrated, and the camera footage was processed with the use of the CODA analysis system (Charnwood Dynamics Ltd, Leicestershire, UK).

EMG was recorded by connecting the electrodes to preamplifier electrode wire which was hardwired to telemetric equipment (TeleMyo2400, Noraxon Inc, Scottsdale, AZ)., with the signal being pre-amplified and transmitted to a computer. The sampling rate was 1500 Hz and the EMG signal was filtered and fully rectified.

Data analysis

The integrated rectified value (iEMG) (μV·s) was calculated for all muscles of the take off and landing legs. The differences between the single and double jumps in iEMG were also calculated as a percentage of the values of the single jumps (subtracting the mean value for the single revolution jumps from the mean value for the double revolution jumps, then dividing by the mean value of the single revolution jump and multiplying by 100). Given that the purpose of the present study was to compare the EMG activity between one and two revolution jumps during take off and landing for a single participant, it was decided to calculate the absolute rather than the normalised values for the EMG signal. This was in line with the recommendations of *Kamen (2004),* who stated that in such investigations reporting the absolute value of the EMG signal is acceptable and can be more meaningful than a relative score derived using normalisation methods.

Results

Toe-Loop

Table 1 shows the iEMG values for all muscles during the take off and landing phases of the single and double toe-loop. The iEMG values at take off increased for all muscles when performing the double revolution jumps. The percentage increase varied among muscles, with the highest increase observed for BF followed by the AD. The landing patterns were slightly different. AD appeared to be the only muscle with a large increase in iEMG during the double toe-loop. Contrary, iEMG for the other three muscles decreased.

Table 1. iEMG readings of the muscles during the take off and landing phases of the single and double toe-loop.

Muscles	iEMG (µV·s)					
	Toe-Loop Take Off (NDL)			Toe-Loop Landing (DL)		
	Single	Double	%Dif	Single	Double	%Dif
Gastrocnemius Medialis	50.8	65.8	29.5	40.6	27.86	-31.4
Biceps Femoris	36.4	98.3	170.1	64.8	29.75	-54.1
Rectus Femoris	83.7	110.4	31.9	72.9	68.72	-5.7
Adductors	21.4	47.4	121.5	24.3	90.34	271.8

Table 2 shows the iEMG values for all muscles during the take off and landing phases of the single and double flip. Similar to the toe-loop jumps, iEMG at the take off phase of the flips increased for all muscles during the double rotation jump, with the AD being the muscle group with the highest percentage increase. For the landing phase of the flip, the AD was again the muscle with the highest percentage increase. Contrary to the toe-loop, a reduction in muscle activation at the landing of the double flip was observed for one muscle group only (GM).

Finally, the iEMG values of the muscles during the landing phase were higher at the flip than at the toe-loop jumps.

Table 2. iEMG readings of the muscles during the take off and landing phases of the single and double flip.

Muscles	iEMG (µV·s)					
	Flip Take Off (DL)			Flip Landing (DL)		
	Single	Double	%Dif	Single	Double	%Dif
Gastrocnemius Medialis	86.0	104.2	21.2	61.1	31.4	-48.6
Biceps Femoris	98.3	172.0	75.0	73.8	83.4	13.0
Rectus Femoris	118.9	222.9	87.5	76.8	168.4	119.3
Adductors	99.9	236.6	136.8	24.8	68.4	175.8

Discussion

The EMG activity for all the muscles tested in the present study suggested that they made an important contribution during both take off and landing. Some interesting patterns were observed for both phases. With respect to the take off phase, it was shown that regardless of DL or NDL (toe-loop) take off, the activity of all muscles increased when the skater performed the double revolution jumps. This suggests that in order to increase the number of rotations performed for a given jump, a skater must increase the activation of all four muscle groups tested

(BF, RF, GM and AD) for the take off leg. It is also worth noting that the percentage increase for each muscle group varied greatly between jumps and revolutions and ranged from 21.2% to 170.1%. This implies that figure skaters might alter the relative contribution of the muscle groups used for a given jump according to the rotations performed. Such information could have important implications for skaters and coaches, as they could be used for the development of individual programmes for the improvement of the strength and flexibility of particular muscle groups, based on the requirements of the figure skating routines of the athletes.

The EMG activity of the muscles varied with the type of jumps and the revolutions performed in the landing phase also (landing on the DL for both jumps). However, although one could expect for the activity of all muscle groups to increase for the double revolution jumps, this was the case only for AD. Contrary, no consistent pattern was identified for the BF and RF, which decreased in the double toe-loop and increased in the double flip, while the muscle activation of GM decreased during the double revolutions in both jumps. Similar to the observations for the take off phase, these findings suggest that the activation of the muscles and their relative contribution during the landing phase of a figure skating jump might differ depending on the number of revolutions performed. Although not examined in the present study, the above differences between one- and two-revolution jumps might also be attributed to potential differences between the body position (and, thus, the muscle activation requirements) at touch down.

Another interesting finding was that the activation of all muscle groups during the landing phase was higher at the flip than at the toe-loop jumps. This might be related to differences in jump requirements, such as body movement in the air, which might influence the performance characteristics of the jumps. For example, the flight time was generally more for the flip than the toe-loop jumps, something that could partially explain the higher EMG patterns observed at the flip landings. In view of the above findings, it would be of interest in future studies to attempt a detailed analysis of the take off and landing phases of figure skating jumps, and to investigate whether any changes in the EMG activity of the muscle groups are associated with changes in other biomechanical parameters of a figure skater's technique.

Conclusion

The purpose of the present study was to provide a first set of data on the EMG activity of lower extremity muscles during the take off and landing phases of one- and two-revolution jumps of a professional figure skater. It was shown that the EMG activity of GM, BF, RF and AD increased at take off during the double revolution jumps, regardless of DL or NDL take off. No similar pattern was observed for the landing phase (with the exception of AD), while the activation of each muscle varied with the type of jump and the number of revolutions. Finally, all muscles showed higher activation patterns during the flip than the toe-loop landings. Considering the noteworthy EMG patterns recorded, future research should focus on testing a large sample of skaters and expanding the number of revolutions used in each jump, in order to confirm these findings, identify any common patterns and allow generalisation of the data. Such information can be of great interest to figure skaters and their coaches, as it enables the identification of the main muscles contributing to the projection of the body in the air, as well as the changes in the muscles' activation between jumps with different number of revolutions. Moreover, given that the muscles activated during landing act to improve the stability and balance of the body and to absorb the impact forces, identification of these muscles is also beneficial, for the purposes of designing appropriate personalised training programmes that could lead to performance improvement.

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