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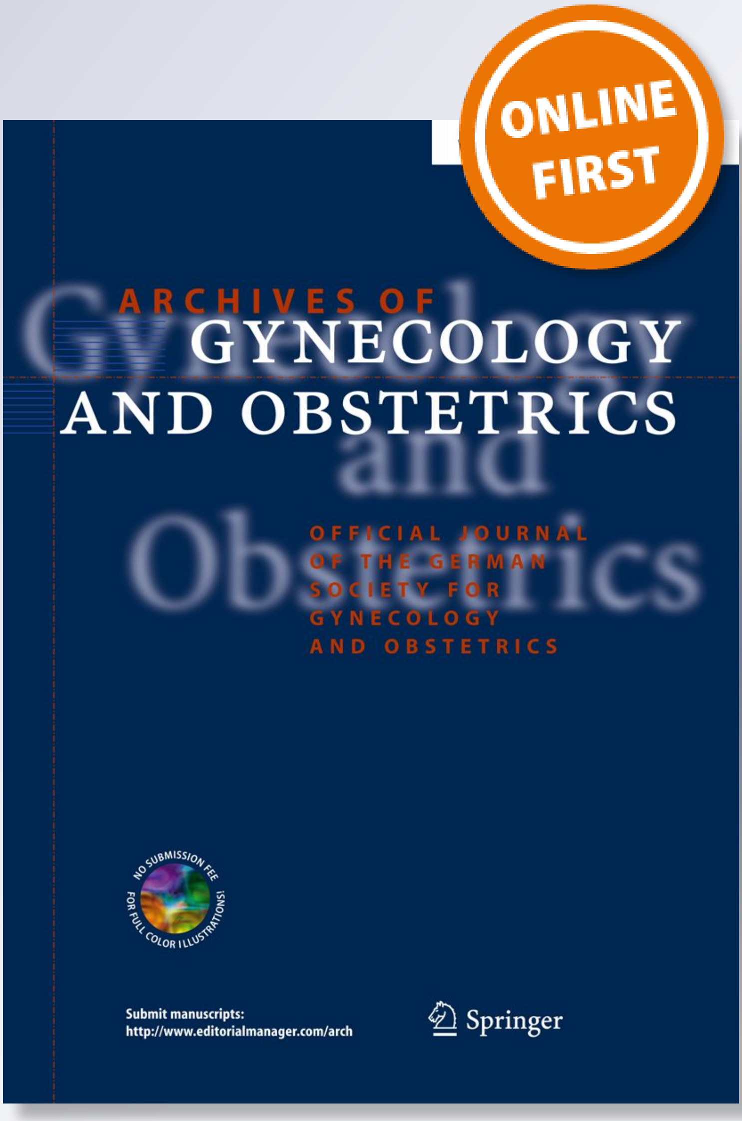
Archives of Gynecology and Obstetrics

ISSN 0932-0067

Arch Gynecol Obstet
DOI 10.1007/s00404-018-4734-4



Springer

Archives of Gynecology and Obstetrics
https://doi.org/10.1007/s00404-018-4734-4

GENERAL GYNECOLOGY

Pelvic floor muscle activity during jumps in continent and incontinent women: an exploratory study

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Received: 20 November 2017 / Accepted: 4 March 2018

Abstract

Purpose Stress urinary incontinence (SUI) symptoms can be provoked during impact loads such as vertical jumps. To investigate and compare pelvic floor muscle (PFM) activity in women with SUI and continent women (CON) during drop jumps (DJ) and counter movement jumps (CMJ) could clarify the activity of the PFMs during impact loads.

Methods A tripolar vaginal probe was used to record surface electromyographic (EMG) activity of the PFMs during DJ and CMJ. Time intervals of 30 ms were used to parameterize data from 30 ms before (pre-activity) to 150 ms after (reflex activity) ground contact on a force plate during the landing and take-off phase. EMG signals were normalized to the mean of the peak values of two maximal voluntary contractions (MVC) and expressed in percentage (% MVC).

Results For all time intervals during the landing and take-off phase, no statistically significant differences could be found between women with SUI and CON. EMG values exceeded 100% MVC for all time intervals during all landing and take-off phases. Maximal PFM activation was measured during the first landing of DJ and was 404.1% MVC for SUI and 370.2% MVC for CON.

Conclusions Vertical jumps seem to stimulate pre-activity before and reflex activity after ground contact during the landing phase and activate PFMs up to 400% MVC. Jumping stimuli inducing involuntary PFM contraction could show a beneficial factor to be integrated in a PFM rehabilitation program.

Keywords Activation · Electromyography · High impact · Pre-activity · Reflex-activity

Introduction

Urinary incontinence is worldwide a big issue. About every fourth woman is affected and suffers from the related social burden, like social isolation, impact on work performance, negative feelings, interference of sexual life, and abandonments of sport [1–4]. Looking at all different forms of incontinence, stress urinary incontinence (SUI) is the most common one, affecting young and old women [1]. Young sportive women report SUI from 0 to 80%, depending of the physical activities, their intensity and impact [1, 2]. The prevalence is higher during high-impact activities; especially trampolinists and volleyball players show a high prevalence rate from 65.7 to 80% [1–3].

Until now little is known about the mechanism of pelvic floor muscles (PFMs) during high-impact activities, even though it is one of the most demanding factors of SUI (complaint of involuntary leakage on effort or physical exertion or on sneezing or coughing) [3, 4]. Two opposing hypotheses

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Published online: 10 March 2018

exist concerning the pathophysiology in sportive women with SUI. Impact activities could strengthen the PFMs or they may overload and weaken the pelvic floor structures [2]. Findings of increased cross-sectional area of PFMs in women practicing high-impact activities support the strengthening theory [5]. Strenuous exercise may be a causative factor for developing SUI but it could also reveal a latent SUI problematic, which is unrevealed by inactive women [6]. Better understanding of PFMs mechanism during high-impact activities, such as vertical jumps, could be crucial for the development of specific PFM rehabilitation regimes including involuntary or reflexive PFM contractions [3, 7, 8].

As one of high-impact activities running is investigated concerning the biomechanics of PFMs [9, 10]. Luginbuehl et al. measured surface electromyographic (EMG) activity of PFM during running in healthy women and detected a PFM activity of over 100% MVC (normalized EMG on maximal voluntary contraction) during running at 11 km/h speed [9]. Leitner et al. compared continent and incontinent women during three different running speeds and in this study SUI women showed a PFM activity of up to 200% MVC at a running speed of 15 km/h [10]. Impact activities not only induce high PFM activities during running but it also produces a pre-activity and reflex activity of the PFMs [9, 10]. Smith et al. observed delayed postural activation of PFM during rapid arm movements by SUI women [11]. This suggests that the pre-activity phase and force generation of PFM is crucial for female continence [12].

Mechanisms and performance during drop jumps (DJ) and counter movement jumps (CMJ) are well investigated concerning ground reaction forces, leg muscle pre-activity and reflex activity, drop height and the stretch and shortening cycle (SSC). The SSC is a combination of eccentric and concentric muscle action and has been observed during vertical jumps [13]. During DJ the pre-activity and eccentric phase of agonist muscles (m. vastus medialis and lateralis) are higher than in CMJ [14]. During vertical jumps high impacts are developed. Weinhandel et al. measured peak vertical ground reaction force of 20.2 ± 5.3 N/kg for female athletes during DJ [15]. Nevertheless, to the best of our knowledge nothing is known about PFM activity during jumps.

The study aimed to compare PFM activity between continent and incontinent women during vertical jumps. Of main interest was the PFM pre-activity phase, reflex activity and the maximal and minimal PFM activity during vertical jumps.

Materials and methods

Study design and subjects

A cross-sectional, exploratory design was considered to investigate PFM activity during two different vertical jumps for continent and incontinent women. The research design was approved by the ethics committee of the Canton of Bern, Switzerland (No. 391/14) and written consent was obtained from all participants.

Twenty-eight continent and twenty-two incontinent women aged between 18 and 60 years were recruited by flyer. Inclusion criteria were a diagnosis of SUI or being continent according to the ICIQ-UIsf and personal history, ability to jump, BMI between 18 and 30 kg/m^2, ability to read and understand German, a negative pregnancy test for women of childbearing age and parous women at least 12 months postpartum and without breastfeeding. Exclusion criteria were acute urinary tract or vaginal infections, past urogenital surgery, overactive bladder as main complaint and urogenital prolapse > grade 1 according POP-Q [16]. An urogynaecologist (A.K.) performed the screening procedure for inclusion criteria.

Instrumentation and data collection

A tripolar vaginal probe (STIMPON™ Innocept Biobedded Systems GmbH, Gladbeck, Germany, patent number EP 0 963 217 B1, CE 0482) (Fig. 1) in a differential configuration was used to record EMG activity of the right PFM and a ProDry™ tampon (Innocept Biobedded Systems GmbH, Gladbeck, Germany) (Fig. 2) soaked beforehand in a physiologic saline solution was pulled over the three electrodes of the vaginal probe. According to the SENIAM recommendations [17] the reference electrode (Ambu Blue Sensor N, Ballerup, Denmark) was placed on the left anterior superior iliac spine and EMG was acquired by a 16-channel telemetric system (TeleMyo 2400 G2, Noraxon USA Inc., Scottsdale, AZ, USA; sampling rate 3000 Hz, gain 1). The right electrode pair was connected by wire with integrated pre-amplifier (baseline noise < 1 µV RMS; input impedance > 100 MΩ; common mode rejection ratio > 100 dB;

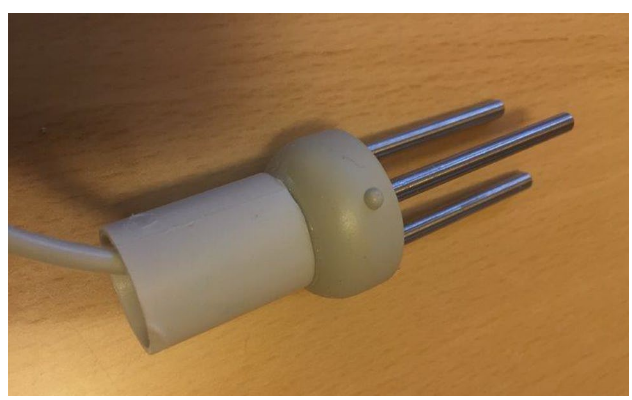

Fig. 1 Vaginal probe. Tripolar vaginal probe (STIMPON™ Innocept Biobedded Systems GmbH, Gladbeck, Germany, patent number EP 0 963 217 B1, CE 0482)

Fig. 2 Vaginal probe and sensor. Tripolar vaginal probe (STIMPONTM Innocept Biobedded Systems GmbH, Gladbeck, Germany, patent number EP 0 963 217 B1, CE 0482) costumized with a plastic sleeve and covered by a ProDryTM tampon (Innocept Biobedded Systems GmbH, Gladbeck, Germany). The imaged probe was a sample

input range ± 10 µV; base gain 500; integrated band-pass filter 10–500 Hz) to the transmitter of the telemetric system. Before each measurement session the impedance of the electrode pair was measured (Digitimer model D175, Digitimer Ltd., Welwyn Garden City, UK) and values ≤ 2 kΩ were accepted. All participants wore standardized shoes (Adidas, Duramo 6). To detect impacts during landing and take-off a force plate (Type 9286BA, Kistler Winterthur, Switzerland) was used.

Testing procedure

Women who had an empty bladder were instructed in a standardized way to contract PFMs. Vaginal palpation with assessment of avulsion was performed in supine by two specialized therapists. PFM strength was tested and graded according to the modified Oxford grading system [18]. The correct placement of the probe, inserted by the subjects themselves was verified. PFM activity at rest was recorded during 30 s, followed by a 5-s MVC done twice with a resting time of 15 s in between. After standardized instructions for executing CMJ and DJ and a verification of the correct execution, PFM EMG and force plate signals were recorded during three repetitions of DJ and CMJ. Between each jump several seconds of rest were required and each jump was performed bipedal, followed by a soft landing on both feet. The women were asked to jump as high as possible and to land again on the force plate. During DJ the women were instructed to drop off from a 21 cm high box, to minimize the duration of ground contact and to perform a maximal jump after landing. In CMJ the women started from an upright standing position, performed a quick flexion of the knees preceding the jump [19]. Women received no instructions concerning PFM contraction.

Data processing and analysis

EMG data were processed by custom software in Matlab (Version 2013a, The Math-Works Inc., Natick, MA) and the signal quality was assessed by visual inspection. The raw EMG signal was 20 Hz high-pass and 500 Hz low-pass filtered (second-order Butterworth filters, zero-lag). Data demonstrating evidence of movement artifact were excluded.

According to Hodges and Bui [20] the EMG activity onset threshold (onset ON) was set as the mean plus two standard deviations of the filtered and rectified EMG signal during the 30-s rest period.

A moving root mean square (RMS) procedure (time window 200 ms) was applied to smooth the EMG of MVC (EMG_{MVC}) measurements. For EMG normalization the peak values of the smoothed EMG_{MVC} within the 5-s contractions were taken and the mean of the two MVC peak values was calculated for the reference value (100% MVC).

The first landing (T_0), take-off (T_1) and second landing (T_2) from DJ and take-off (T_1) and landing (T_2) from CMJ measurements were parameterized according to Fleischmann et al. [12]. To receive information on pre-activity the timeline started 30 ms prior to each landing (− 30 to 0 ms), respectively, take-off from DJ and CMJ. For reflex activity the time intervals of 30 ms (0–30), (30–60), (60–90), (90–120), (120–150) ms after landing or take-off were analyzed. To specifically analyze the take-off (T_1) a time interval of − 350 to 300 ms was applied.

RMS values within the parameterized time intervals were calculated to obtain EMG outcomes and a mean was taken of the three vertical jumps. Additionally the maximal EMG value (EMG_{max}) and its time point ($tEMG_{max}$) with respect to the landing or take-off event was extracted for the time interval from − 30 to 150 ms. For the time interval from − 350 to 300 ms during take-off maximal and minimal EMG value (EMG_{maxT}, EMG_{minT}) and its time point ($tEMG_{maxT}$, $tEMG_{minT}$) were extracted. T_0 to T_2 were determined from the force plate with a threshold set at 20 N.

Statistical analysis

SPSS software (Version 23.0 for Windows, SPSS Inc., Chicago, IL) was used to perform the statistical analysis. All variables were tested on normal distribution with the Kolmogorov–Smirnov test prior to inferential statistics. For the demographic data and all time variables parametric descriptive statistics (see Table 1) were applied. A *t* test was used to analyze differences between groups for demographic, EMG onset and time data. For ordinal ICIQ-UI-sf and Oxford-grade scales a non-parametric Mann–Whitney *U* test were performed. To identify within and between effects (in the time interval from − 30 to 150 ms) an analysis of variance for repeated measures (two groups, six EMG variables, two vertical jumps) was applied. Statistical significance was considered as $P < 0.05$.

Results

Twenty-two incontinent (SUI) and 28 continent (CON) women were included. Participants' baseline demographics are presented in Table 1. A significant difference between groups could be detected for age and ICIQ-UI-sf, but not for BMI and Oxford grade groups. Descriptive statistics of the EMG variables of the three DJ and CMJ are displayed in Tables 2 and 3.

In the six time intervals during DJ (first landing, take-off, second landing) and CMJ (take-off, landing), no significant statistical differences could be found between continent and incontinent women, neither for EMG_{max} values nor for the time needed to reach EMG_{max} ($tEMG_{max}$) (all $P < 0.05$).

Table 1 Demographics of the participants

	CON	SUI	Significance *P*
Participants, *n*	28	22	
Age, years	38.7 (10.0)	45.3 (9.5)	0.018[a]
Height, m	167.0 (5.7)	168.2 (5.3)	0.927[a]
Weight, kg	60.9 (6.2)	60.7 (7.3)	0.911[a]
BMI, kg/m^2	21.8 (1.7)	21.4 (2.0)	0.806[a]
ICIQ-UI-sf, 0–21	0 (1)	6 (3)	< 0.001[b]
Oxford, 0–5	5 (1)	5 (1)	0.565[b]

Arithmetic mean (standard deviation) or median (interquartile rate) or absolute frequencies and significance test

n numbers

[a]*t* test

[b]Mann–Whitney *U* test

Table 2 Descriptive statistics (mean ± SD) for EMG outcomes in six time intervals, EMG maximum (EMG_{max}), time of EMG_{max} ($tEMG_{max}$), EMG maximum before take off in time interval − 350 to 0 ms (EMG_{maxT}), time EMG maximum before take off in time interval − 350 to 0 ms ($tEMG_{maxT}$), EMG minimum after take off in time interval 0–300 ms (EMG_{minT}), time EMG minimum after take off in time interval 0–300 ms ($tEMG_{minT}$), onset of activity (ON) derived from EMG during drop jumps (DJ) for first landing, take off and second landing in continent (CON) and incontinent (SUI) women

DJ	Variable	CON (mean ± SD)	SUI (mean ± SD)
First landing	$T_{-30–0}$ (% MVC)	136.3 ± 87.5	171.2 ± 88.3
	$T_{0–30}$ (% MVC)	171.5 ± 85.1	192.6 ± 95.9
	$T_{30–60}$ (% MVC)	193.4 ± 74.0	220.8 ± 119.7
	$T_{60–90}$ (% MVC)	207.1 ± 99.3	225.0 ± 90.6
	$T_{90–120}$ (% MVC)	203.1 ± 98.5	224.6 ± 91.4
	$T_{120–150}$ (% MVC)	211.9 ± 101.0	230.4 ± 100.4
	EMG_{max} (% MVC)	370.2 ± 139.1	404.1 ± 164.1
	$tEMG_{max}$ (ms)	154.9 ± 61.8	141.5 ± 53.3
Take off	$T_{-30–0}$ (% MVC)	164.6 ± 93.6	173.7 ± 84.5
	$T_{0–30}$ (% MVC)	157.9 ± 79.5	156.6 ± 85.2
	$T_{30–60}$ (% MVC)	122.2 ± 57.4	140.6 ± 94.4
	$T_{60–90}$ (% MVC)	126.5 ± 71.3	133.6 ± 78.8
	$T_{90–120}$ (% MVC)	114.9 ± 57.0	124.6 ± 81.1
	$T_{120–150}$ (% MVC)	107.9 ± 52.0	112.7 ± 60.0
	EMG_{max} (% MVC)	231.1 ± 108.2	247.8 ± 135.7
	$tEMG_{max}$ (ms)	76.3 ± 64.8	72.3 ± 57.7
	EMG_{maxT} (% MVC)	334.4 ± 297.6	318.6 ± 209.4
	$tEMG_{maxT}$ (ms)	− 131.8 ± 69.9	− 146.9 ± 66.9
	EMG_{minT} (% MVC)	50.0 ± 29.4	57.9 ± 42.6
	$tEMG_{minT}$ (ms)	214.1 ± 82.4	210.0 ± 96.3
Second landing	$T_{-30–0}$ (% MVC)	132.0 ± 53.1	158.6 ± 78.1
	$T_{0–30}$ (% MVC)	151.4 ± 64.9	172.4 ± 75.8
	$T_{30–60}$ (% MVC)	148.7 ± 79.4	182.1 ± 91.8
	$T_{60–90}$ (% MVC)	144.6 ± 65.6	167.1 ± 81.6
	$T_{90–120}$ (% MVC)	136.7 ± 71.8	166.7 ± 79.3
	$T_{120–150}$ (% MVC)	103.4 ± 47.0	126.8 ± 90.6
	EMG_{max} (% MVC)	241.1 ± 100.5	297.2 ± 140.6
	$tEMG_{max}$ (ms)	71.0 ± 37.6	57.1 ± 32.0
	ON (% MVC)	40.6 ± 16.2	37.3 ± 23.1

During DJ and CMJ a significant increase of EMG pre-activity and reflex activity (valid for all six time intervals) was found (Figs. 3, 4, 5, 6). During DJ the time interval values of the first landing varied from 136.3 to 225.0% MVC, for the second landing from 103.4 to 182.1% MVC and for CMJ from 145.5 to 205.0% MVC. The take-off of DJ varied from 107.9 to 173.7% MVC and for CMJ from 117.5 to 209.3% MVC. A significant difference from PFM activation ON to mean PFM EMG activity of the six time intervals was detected ($P<0.05$). ON values were calculated 40.6 ± 16.2% MVC for continent and 37.3 ± 23.1% MVC for incontinent women.

EMG_{max} values during the first landing of DJ varied from 370.2 to 404.1% MVC and during the second landing from 241.1 to 297.2% MVC (Fig. 3) and for CMJ from 314.6 to 342.2% MVC (Fig. 4). During take-off in the time interval from − 30 to 150 ms values varied from 231.1 to 247.8% MVC for DJ and 248.3–302.0% MVC for CMJ. For take-off in the time interval from − 350 to 0 ms the EMG_{maxT} values varied from 318.6 to 334.4% MVC for DJ (Fig. 5) and 314.6 to 342.2% MVC for CMJ (Fig. 6).

To reach the maximal EMG activity ($tEMG_{max}$) during DJ in the first landing it took between 141.5 and 154.9 ms, for the second landing between 57.1 and 71.0 ms (Fig. 3) and for CMJ between 83.3 and 100.0 ms (Fig. 4). For take-off in the time interval from − 30 to 150 ms it took between 72.3 and 76.3 ms for DJ and between 75.9 and 90.0 ms for CMJ. For take-off in the time interval from − 350 to 0 ms ($tEMG_{maxT}$) it took between − 146.9 and − 131.8 ms for DJ (Fig. 5) and between − 205.3 and − 169.1 ms for CMJ (Fig. 6).

The minimal EMG activity between the take-off and second landing phase (EMG_{minT}) was between 50.0 and 57.9% MVC for DJ (Fig. 5) and during CMJ between 51.1 and 61.4% MVC (Fig. 6).

To reach the minimal EMG activity ($tEMG_{minT}$) after take-off it took between 210.0 and 214.1 ms for DJ (Fig. 5) and 237.5 and 252.0 ms for CMJ (Fig. 6).

A significant difference of EMG values was detected within the six time intervals ($P<0.05$) during DJ and CMJ, for all landings and take-offs as well as in both groups.

Table 3 Descriptive statistics (mean ± SD) for filtered and smoothed electromyographic (EMG) outcomes in six time intervals, maximal EMG (EMG_{max}), time of EMG_{max} ($tEMG_{max}$), maximal EMG before take-off in time interval − 350 to 0 ms (EMG_{maxT}), time maximal EMG before take-off in time interval − 350 to 0 ms ($tEMG_{maxT}$), minimal EMG after take-off in time interval 0–300 ms (EMG_{minT}), time minimal EMG after take-off in time interval 0–300 ms ($tEMG_{minT}$), onset of activity (ON) derived from EMG during counter movement jumps (DJ) for first landing, take-off and second landing in continent (CON) and incontinent (SUI) women

CMJ	Variable	CON (mean ± SD)	SUI (mean ± SD)
Take off	T_{-30-0} (% MVC)	175.6 ± 74.6	208.1 ± 123.8
	T_{0-30} (% MVC)	174.7 ± 70.8	209.3 ± 131.9
	T_{30-60} (% MVC)	150.9 ± 64.3	162.9 ± 92.1
	T_{60-90} (% MVC)	152.3 ± 75.8	170.7 ± 99.6
	T_{90-120} (% MVC)	131.6 ± 59.1	132.4 ± 66.2
	$T_{120-150}$ (% MVC)	117.5 ± 48.1	131.3 ± 69.6
	EMG_{max} (% MVC)	248.3 ± 88.7	302.0 ± 155.9
	$tEMG_{max}$ (ms)	75.9 ± 63.7	90.0 ± 80.7
	EMG_{maxT} (% MVC)	314.6 ± 152.1	342.2 ± 192.4
	$tEMG_{maxT}$ (ms)	− 169.1 ± 76.6	− 205.3 ± 85.6
	EMG_{minT} (% MVC)	51.1 ± 23.3	61.4 ± 43.4
	$tEMG_{minT}$ (ms)	252.0 ± 85.3	237.5 ± 102.4
Landing	T_{-30-0} (% MVC)	145.5 ± 56.8	187.1 ± 92.3
	T_{0-30} (% MVC)	174.5 ± 71.2	190.0 ± 90.3
	T_{30-60} (% MVC)	155.9 ± 55.6	205.0 ± 96.8
	T_{60-90} (% MVC)	163.4 ± 87.7	188.5 ± 85.0
	T_{90-120} (% MVC)	164.0 ± 65.7	194.7 ± 93.5
	$T_{120-150}$ (% MVC)	144.3 ± 76.5	160.9 ± 89.3
	EMG_{max} (% MVC)	277.7 ± 112.7	325.0 ± 145.7
	$tEMG_{max}$ (ms)	100.0 ± 57.4	83.3 ± 37.4
	ON (% MVC)	40.6 ± 16.2	37.3 ± 23.1

Discussion

The investigation concerning PFM activation during vertical jumps for continent and incontinent women showed no significant difference between the groups. A tendency could be seen that SUI women show an increased PFM activation, this might be due to the large standard deviation of data or a lower MVC from SUI women. During all time intervals from − 30 to 150 ms of DJ and CMJ of all landings and take-offs a mean EMG and an EMG_{max} exceeding 107.9% MVC was measured. The highest values could be detected during the first landing of DJ. Higher jumps produce a rising ground reaction force and induce higher force demand for PFM during landing [19]. McBride et al. have seen that pre-activity and eccentric muscle activity were significantly higher during DJ than CMJ and that the peak concentric force was highest during DJ for agonist muscles (m. vastus lateralis and medialis). PFMs seem to contract analogically to the agonist muscles.

During the second landing of DJ and the landing of CMJ a similar activation pattern became apparent. The first and second time frame (0–60 ms) showed an increase followed by a decrease in the following time frames (60–150 ms). The first landing of DJ showed an increase during the first three time frames (0–90 ms) and afterwards stagnancy. This could be due of the higher impact during the first landing. Take-off already showed a decrease in PFM activity in the pre-activity phase (− 30 to 0 ms), which continued in the reflex-activity phase. The EMG_{max} values during take-off occurred before take-off and the values were higher for CMJ then for DJ. The minimal EMG activity between the take-off and the second landing phase was between 50.0 and 61.4% MVC, close to the ON values (37.3–40.6% MVC).

A vaginal probe has probably no significant alteration of PFM performance [21]. Additionally the vaginal probe used in this study might show a stabilizing effect, which [2] could have minimized a probable tendency to contract the PFMs to avoid the slip out of the vaginal probe.

During DJ the centrally programmed pre-activity in landing regulates the stiffness behavior of the tendomuscular system around the ankle joint [22]. The extent of pre-activity determines mainly the jump performance [22]. PFM pre-activity is shown in the time interval T_{-30-0} (30 ms before ground contact). During all landings PFM pre-activity was over 132.0% MVC, confirming the importance of the neuromuscular timing. In the systematic review from Moser et al. the timing of PFM activity in relation to other trunk muscles activity or to the raise in intra-abdominal pressure seemed to be a main point in maintaining continence during impact activities [12]. To guarantee continence the PFM activates and produces an urethral pressure increase preceding the raise in intra-abdominal pressure, this could be observed during coughing [11, 23]. A delay in the onset of PFM activity was seen during coughing and rapid arm movements for SUI women [24, 25]. In this study no significant difference concerning timing and PFM activity between SUI and healthy women could be detected.

Strength and limitations

The validity of EMG data may be affected by crosstalk and a displacement of the vaginal probe [26, 27]. During jumps large ground reaction forces are developed and muscle activity from the whole body is required and, therefore, the confounder of crosstalk is almost unavoidable. To decrease the eventuality of recording crosstalk the application of a tripolar vaginal probe in a differential configuration was chosen, as recommended by the SENIAM group (Surface Electromyography for the non-invasive assessment of muscles) [27]. For a solid fit and to minimize motion artifacts the probe was covered by a tampon and completely inserted into the vagina. Furthermore raw EMG data were visually controlled for plausibility and abnormal EMG patterns were not considered in further data processing.

For further studies it could be considered to perform simultaneous EMG measurement of PFMs, trunk and leg muscles during vertical jumps to allow comparison between the PFM activity of the well-studied trunk and leg muscle behaviors, concerning the initialization of the activity and the intensity of the muscle contraction.

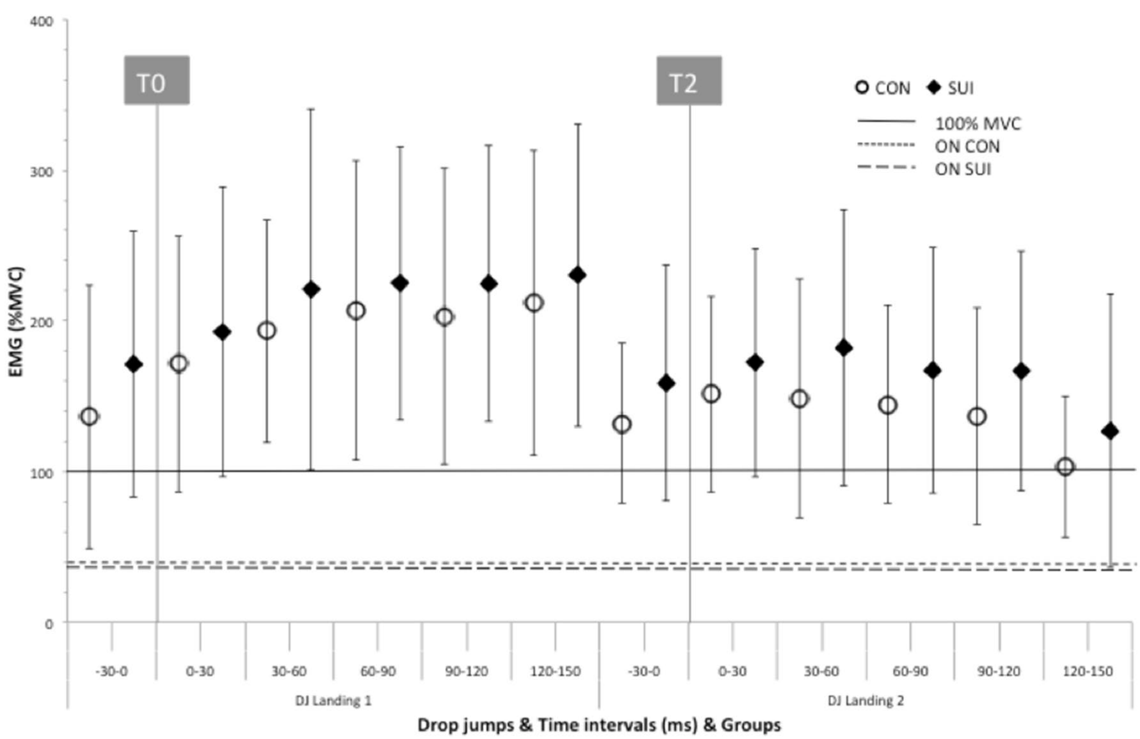

Fig. 3 Means and standard deviations (SD) for landing in the time interval (− 30 to 150 ms) during drop jumps (DJ) for continent (CON) and incontinent (SUI) women. *EMG* electromyographic, % *MVC* normalized EMG on maximal voluntary contraction. *ON CON, ON SUI* EMG onset for CON, SUI, T_0 first landing on the force plate, T_2 second landing on the force plate

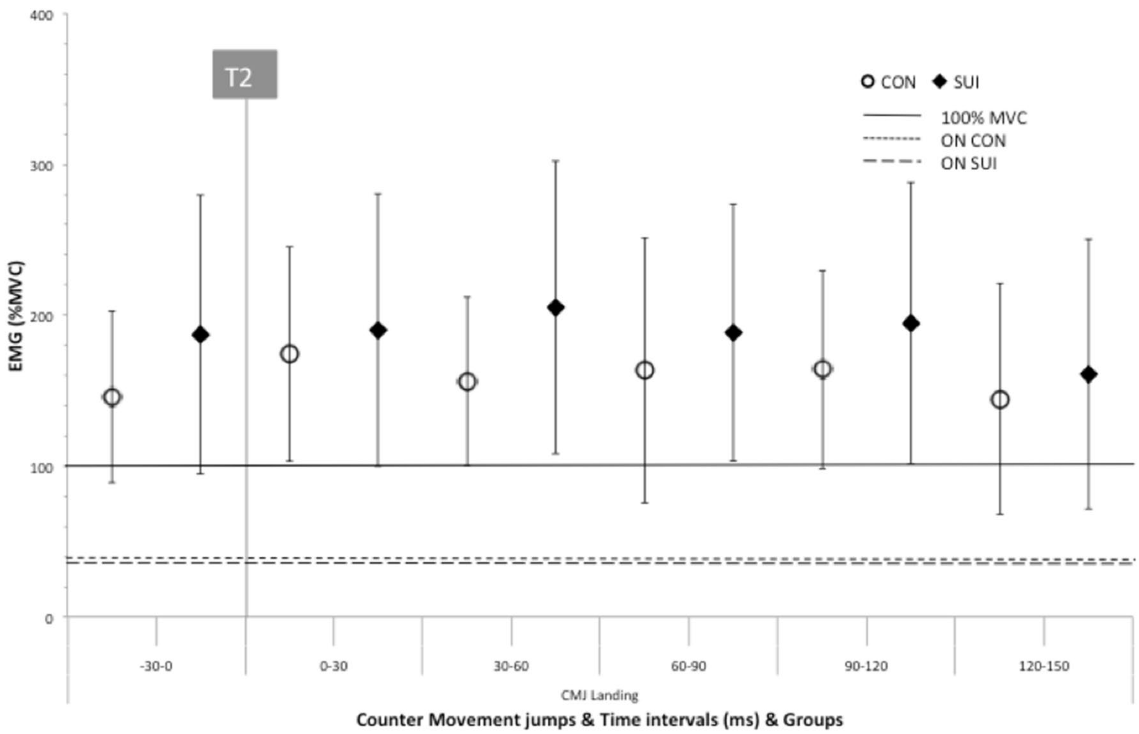

Fig. 4 Means and standard deviations (SD) for landing in the time interval (− 30 to 150 ms) during counter movement jumps (CMJ) for continent (CON) and incontinent (SUI) women. *EMG* electromyographic, *% MVC* normalized EMG on maximal voluntary contraction. *ON CON, ON SUI* EMG onset for CON, SUI, T_2 landing on the force plate

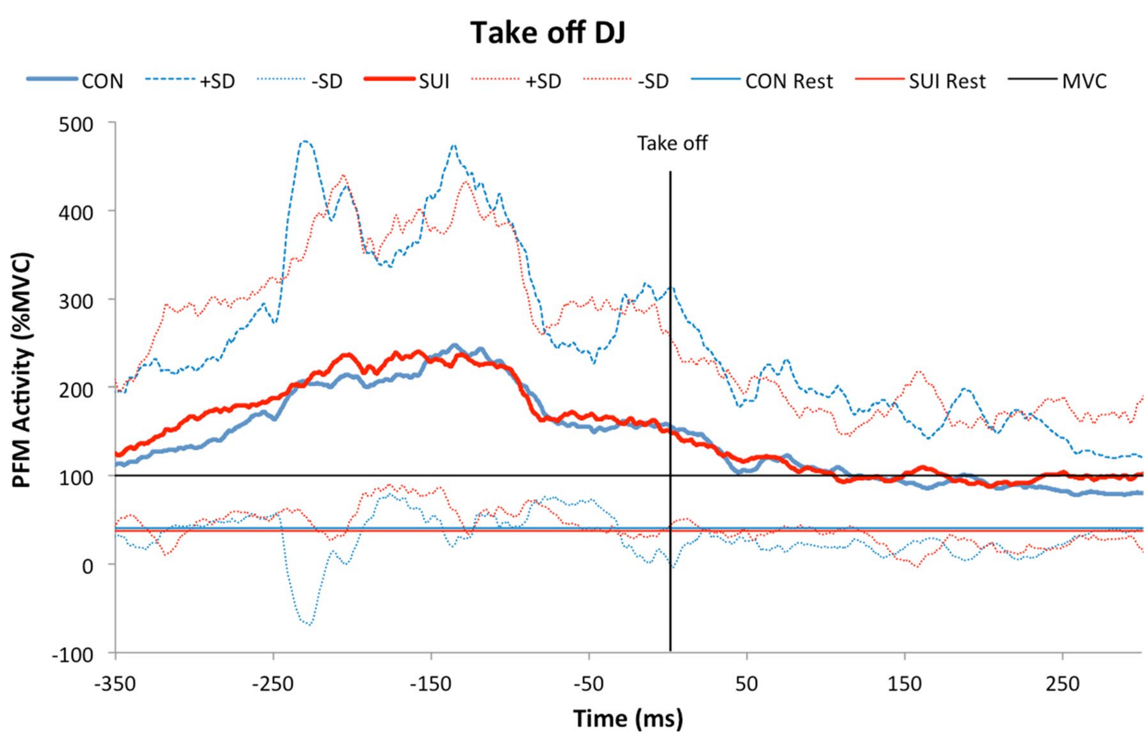

Fig. 5 Means and standard deviations (SD) for take off in the time interval (− 350 to 300 ms) during drop jumps (DJ) for continent (CON) and incontinent (SUI) women. *EMG* electromyographic, *% MVC* normalized EMG on maximal voluntary contraction (MVC), *CON Rest* EMG onset for CON, *SUI Rest* EMG onset for SUI

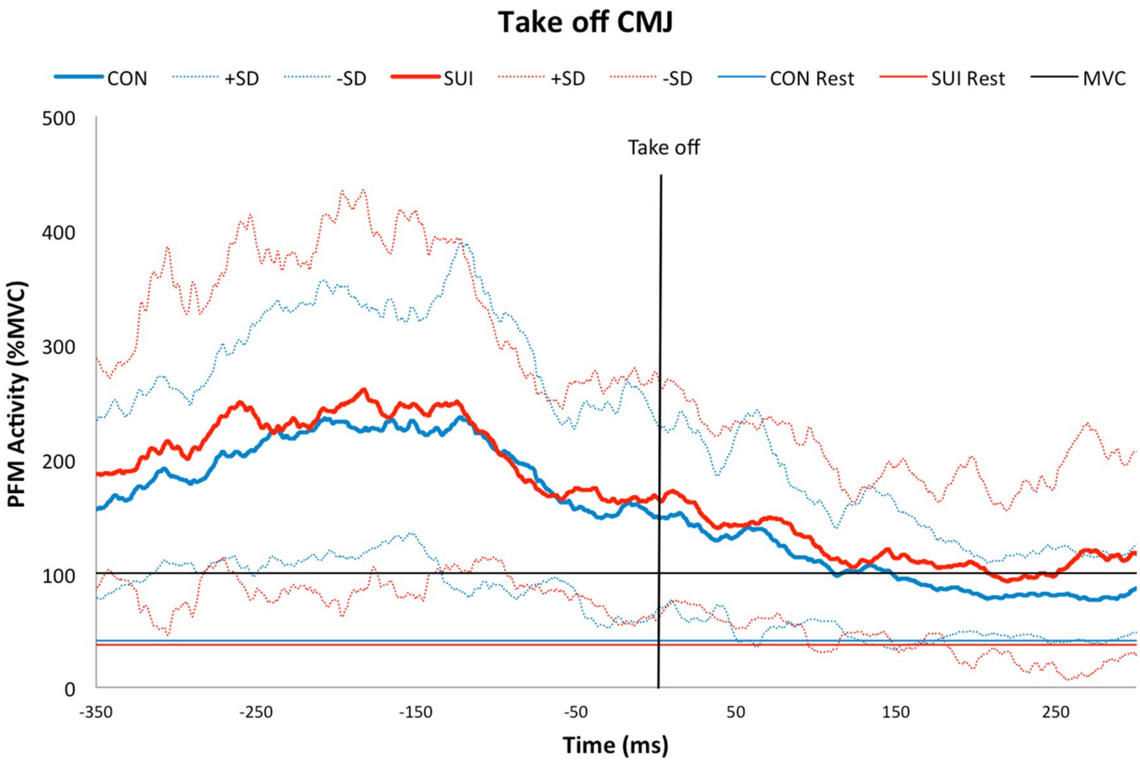

Fig. 6 Means and standard deviations (SD) for take off in the time interval (– 350 to 300 ms) during counter movement jumps (CMJ) for continent (CON) and incontinent (SUI) women. *EMG* electromyographic, *% MVC* normalized EMG on maximal voluntary contraction (MVC), *CON Rest* EMG onset for CON, *SUI Rest* EMG onset for SUI

In this study only women with mild SUI were included, with no significant differences in terms of Oxford grade. This could have added to the fact that this group did not clearly differ from the control group. Further investigations should include subgroups of women with SUI from mild, middle and severe in order to better distinguish the SUI mechanisms.

The missing data of health history such as low back pain, the physical activity behavior as well as the number of deliveries of the two samples are a further limitation. Also the samples had a widespread age from 21 to 58 years. It would be interesting to make subgroups concerning age, parity, physical activities or low back pain.

Conclusion

Investigation of PFM activity during vertical jumps contributes to deepen the knowledge of PFM mechanisms during impact loads that typically trigger urine loss. During the landing phase the PFMs were showing a pre-activity before and reflex-activity after the foot landing without statistical difference within the groups. In SUI women maximal EMG values of 404.1% MVC were measured during a DJ. This raises the question if a PFM rehabilitation program based on MVC and fast voluntary contraction is sufficient to reintegrate SUI women in their normal life and sportive activities, where mainly involuntary PFM activation is occurring. Whether a vertical jump, with its involuntary, reflexive PFM activation is a build-up or an overload for the PFM may depend on the intensity and length of the impact. However, when and to what extent it should be integrated in a rehabilitation program needs to be further investigated.

Acknowledgements Swiss National Science Fondation, Wildhainweg 3, Postfach 8232, 3001 Bern, Switzerland.

Author contributions HM: Project development, Data collection, Data analysis, Manuscript writing. ML: Project development, Data collection. PE: Data analysis, software. AK: Screening procedure for inclusion criteria. J-PB: Adviser, Support of final draft. LR: Project development, adviser, support of final draft.

Compliance with ethical standards

Conflict of interest Nothing to disclose.

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