Received: 13 February 2019 | Accepted: 2 October 2019
DOI: 10.1002/nau.24187

ORIGINAL CLINICAL ARTICLE

Intraday and interday reliability of pelvic floor muscles electromyography in continent woman

Ronja Scharschmidt[1] | **Steffen Derlien**[1] | **Tobias Siebert**[2] | **Marco Herbsleb**[3] | **Norman Stutzig**[2]

[1]Institute of Physiotherapy, University Hospital Jena, Jena, Germany

[2]Institute of Sport and Movement Science, University of Stuttgart, Stuttgart, Germany

[3]Department of Sports Medicine and Health Promotion, University of Jena, Jena, Germany

Correspondence
Ronja Scharschmidt, Institute of Physiotherapy, University hospital Jena, Am Klinikum 1, 07747 Jena, Germany.
Email: Ronja.Scharschmidt@med.uni-jena.de

Abstract

Aims: Vaginal surface electromyography (sEMG) is a tool used for the diagnosis and therapeutic intervention of urinary incontinence. Current sEMG systems differ in regard to electrode arrangement and data reproducibility. The aim of this study was to determine the intrasession, intraday, and interday reliabilities of sEMG parameters using a probe with circumferential electrode-position.

Methods: The intrasession, intraday, and interday reliabilities of maximum isometric voluntary contractions (MVC) of the pelvic floor muscles were assessed for 19 healthy continent women. Three sEMG parameters that are used to describe muscle activity were verified: maximal EMG (EMG_{max}), mean over 500 ms around EMG_{max} ($EMG_{A0.5}$), and mean over 2 seconds during MVC plateau ($EMG_{A2\text{-}4}$). Relative and absolute reliability parameters were calculated, and the statistical methods described by Bland and Altman were applied to the data.

Results: We observed substantial reliabilities for all obtained parameters (EMG_{max}, $EMG_{A2\text{-}4}$, and $EMG_{A0.5}$) in regard to the intrasession measurements (ICC = 0.93-0.97; CI = 0.86-0.99). Overall, the intraday reliability has been moderate (ICC = 0.64-0.75; CI = 0.27-0.90). EMG_{max} (ICC = 0.75; CI = 0.45-0.90) and $EMG_{A2\text{-}4}$ (ICC = 0.73, CI = 0.42-0.89) were higher than $EMG_{A0.5}$ (ICC = 0.64; CI = 0.27-0.85). However, the interday reliability was only fair for EMG_{max} (ICC = 0.48; CI = 0.04-0.77) and $EMG_{A0.5}$ (ICC = 0.51; CI = 0.07-0.78) but moderate for $EMG_{A2\text{-}4}$ (ICC = 0.65; CI = 0.28-0.85).

Conclusions: This intrasession, intraday, and interday reliability results are similar to the results reported in the literature using probes with longitudinally oriented bars. The mean sEMG signal over 2 seconds ($EMG_{A2\text{-}4}$) exhibited the highest reliability and is recommended for further studies. The interday reliability might be enhanced by considering the menstruation cycle.

KEYWORDS
electrode arrangement, maximum isometric voluntary contractions, reproducibility data, urinary incontinence, vaginal probe

Abbreviations: MVC, maximal isometric voluntary contraction; PFM, pelvic floor muscles; sEMG, surface electromyography.

1 | INTRODUCTION

Pelvic floor muscles (PFMs) are important for controlling urinary and fecal excretion as well as during sexual intercourse. PFM activity has been found to decrease during the female life span[1] and decreased PFM activity is associated with stress urinary incontinence.[2] Vaginal surface electromyography (sEMG) is a common tool to examine changes of PFM activity and is used by researchers and clinicians. Reliable sEMG systems are required to examine changes of PFM activity

Several sEMG procedures are used to analyze muscular activity and have been reported in the literature.[3] The most popular of these measurements are muscular activity during maximal voluntary contractions (MVCs) of the PFM and during coughing.[3-6] Raw sEMG data are typically processed using a bandpass filter as well as rectifying and smoothing via the root mean square or moving average. Based on these data different parameters (eg, integration overtime during MVC, maximal, or mean sEMG parameters) are used for further analyses.[3-6]

In recent studies these sEMG parameter were analyzed for intrasession, intersession, and interday reliability. The intrasession reliability revealed good to high reliability based on the intraclass-correlation coefficient (ICC)[4,7] but also high standard errors of measurement (SEM) and high minimal differences.[7] Furthermore, during walking[8] and coughing,[9] good to high intrasession reliabilities were observed. Grape et al[10] examined the intersession reliability and found good reliabilities (ICC = 0.83-0.96) for all parameters. Furthermore, good to high reliability was also observed for the interday reliability using an integrated EMG amplitude sampled at 10 Hz during MVCs.[10,11] However, Glazer et al[11] only reported Pearson's correlation coefficient, which cannot assess systematic bias and depends greatly on the range of values in the sample.[12,13] However, Auchincloss et al[4] observed only poor interday reliability. Interestingly, all of the presented reliability studies were performed using probes with longitudinally oriented bars around the probe.

Currently, there exists no golden standard for sEMG probes regarding its electrode-position.[14] In general, the electrodes are located on the surface of the probe as longitudinally oriented bars or circumferential bands. Both models of electrode positions are used by researchers and clinicians. To the best of our knowledge, there is only one study that examines the reliability of probes with a circumferential electrode-position.[15] Based on the coefficient of variation and the correlation coefficient, the study revealed low interday reliability for sEMG during MVC. Unfortunately, important methodological information was not reported (eg, the analyzed sEMG parameter, the kind of correlation coefficient, and the number of MVCs). Therefore the intrasession, intersession, and interday reliabilities of measurements using sEMG probes with a circumferential electrode-position are still unknown.

The aim of the present study is to test a probe in a circumferential electrode-position to determine intrasession, intersession, and interday reliabilities. Different commonly used sEMG parameters will be analyzed. Based on the recommendation for conducting reliability studies,[12] different statistical methods were used to calculate reliability: (a) relative reliability (ie, when individual measurements vary between one group, the position within the group will be the same); (b) absolute reliability (ie, the extent of variations during repeated measurements).

2 | MATERIALS AND METHODS

2.1 | Participants

Nineteen continent and nulliparous women (age $= 25 \pm 2.89$ years, body mass index $= 22 \pm 1.13$ kg/m^2) participated in the experiments. Inclusion criteria were continence. Exclusion criteria were menses, active implant, metal implant inflammation of the skin at the pelvic floor, or age over 40 years. These criteria were tested by a questionnaire. There were queries about age, week of the menstrual cycle, number of pregnancies, activity at week, experience in specific pelvic floor training, and a questionnaire for bladder function.[16] The questionnaire for bladder function showed continence of all patients so they could be included in the study. The participants were heterogenic in activities (4.0 ± 2.8 hours/We), but there was no influence to test and retest values ($P = .104$ to .879). No woman had experience in specific pelvic floor training. The participants were informed about the aim and risks of the study and gave their written consent.

The menstruation of a woman was subdivided into 4 week sections: proliferation, secretion, ischemia, and menses. During menses, no measurements were taken. The group of participants was split into two subgroups in which intraday measurements (T1-T2) were taken: (a) a proliferation group and (b) a secretion group.

2.2 | Study protocol

Experiments were performed at three test times: T1 and T2 were conducted on the same day separated by 30 minute, and T3 was conducted 1 week later. T1 and T3 were analyzed to determine the intrasession reliability, T1 and T2 to analyzed intraday reliability, whereas T1 and T3 were used to determine the interday reliability.

This study was not blinded. The participants received no feedback during MVC.

The room temperature and humidity were regulated and varied between 22°C ± 2°C and 52% ± 6%, respectively. Before the experiment began, participants were asked to empty their bladder to standardize bladder pressure. Then, the participants took the measurement position (supine position, 45° hip angle, 90° knee angle). The vaginal probe was covered with 5 mL of water-soluble lubricant and was transvaginally inserted by the participants themselves for each test time (T1, T2, and T3). The probe was reinserted before each test session.

Afterward, the participants performed a 5-min warm-up of their PFM consisting of 13 sub-MVCs while breathing out. Each contraction lasted 5 seconds and was progressively increased. Between the last two contractions, there was a 55 seconds break. After the warm-up, there was a 1-minute break.

The main experiment consisted of six MVC. Each MVC was performed for 5 seconds followed by a 55 seconds break. These six MVCs were used to analyze the intrasession reliability.

It is known that the maximum muscle activity depends on the measurement position, where a standing position has the highest pelvic floor activity followed by the sitting and laying positions.[9] The present study examined MVC in the supine position for avoiding measuring muscle activity associated with controlling stabilization.

2.3 | Vaginal sEMG

The EMG system "Syntic" with a bipolar vaginal probe (ti1020 Tic Medizintechnik GmbH & Co. KG, 46286 Dorsten, Germany) was used to record the PFM activity.

The insertion portion of the probe (size = 8 cm, diameter = 2.5 cm, weight = 92 g) consists of two 1-cm broad electrodes and one referent electrode. It was circumferential around the vaginal probe (Table 4). The distance between the electrodes was 1 cm,[15] and the electrical conductivity was standardized using 5 mL of water-soluble lubricant.

The EMG amplifier had a common-mode rejection of 100 dB. The data were recorded at 1600 Hz and filtered. The testing range was 1 to 500 μV with an accuracy of 1 μV. The data were adjusted to zero and were rectified and smoothed using a moving average filter over 2 ms and then sampled down to 100 ms. A high-pass filter was used to eliminate motion artefacts.

2.4 | Parameters

Based on the processed signal, EMG parameters were calculated as follows:

- EMG_{Max}: maximal EMG amplitude score during MVC
- $EMG_{A0.5}$: average A0.5 seconds round the EMG amplitude score during MVC
- $EMG_{A2\text{-}4}$: average 2 to 4 seconds round the EMG amplitude score during MVC

For analyzing the intrasession, intraday, and interday reliability, the three highest MVC (EMG_{max}) values were determined and averaged. The two parameters ($EMG_{A0.5}$ and $EMG_{A2\text{-}4}$) were calculated based on the averaged data.

2.5 | Statistical methods

Mean and standard deviation values were calculated for all parameters. All data were tested for normality using the Shapiro-Wilk test, and 95% confidence intervals were calculated. The groups (proliferation and secretion) were analyzed for significant differences. In the case of normal distributed data, the Student *t* test for independent samples was used. Otherwise, the Mann-Whitney *U* test was used for calculation.

2.6 | Relative reliability

The relative reproducibility is the degree to which individuals maintain the experimental conditions (eg, their position in a sample with repeated measurements[17]) and is assessed using a correlation coefficient.[17] Therefore, the Pearson correlation

TABLE 1 Intrasession reliability from maximal voluntary contraction (MVC) of vaginal surface electromyography (EMG) (relative and absolute statistical variables of the parameters): maximal EMG amplitude (EMG_{max}), 0.5 seconds round maximal EMG amplitude ($EMG_{A0.5}$), and 2 to 4 seconds round maximal EMG amplitude ($EMGA_{2\text{-}4}$)

Parameter	M (±SD), μV	CC; *P* value	ICC (95% CI)	SEM	CV (%)	MDC
EMG_{max}	40.9 (±17.6)	0.82–0.91; <.001	0.933 (0.86-0.97)	10.4	43.0	28.9
$EMG_{A0.5}$	32.1 (±15.4)	0.81–0.88; <.001	0.932 (0.86-0.97)	9.1	48.0	25.3
$EMG_{A2\text{-}4}$	23.5 (±14.1)	0.82–0.91; <.001	0.971 (0.94-0.99)	8.3	60.0	23.1

Note: Pearson CC with significance (*P* value).

Abbreviations: CC, coefficient of correlation; CI, confidence interval; CV, coefficient of variation; ICC, intraclass-correlation coefficient; MDC, minimal detectable change.

TABLE 2 Intraday reliability from MVC of vaginal surface EMG (relative and absolute statistical values of the parameters): maximal EMG amplitude (EMG_{max}), 0.5 second round maximal EMG amplitude ($EMG_{A0.5}$), and 2 to 4 seconds round maximal EMG amplitude ($EMG_{A2\text{-}4}$)

Parameter	M (±SD), µV	CC; P value	ICC (95% CI)	SEM	CV (%)	MDC
EMG_{max}	46.4 (±18.2) 44.8 (±17.0)	0.74; <.001	0.75 (0.45-0.90)	8.8	38.5	24.3
$EMG_{A0.5}$	32.1 (±14.5) 31.8 (±15.3)	0.63; <.002	0.64 (0.27-0.85)	7.8	46.8	21.5
$EMG_{A2\text{-}4}$	26.6 (±15.0) 26.8 (±14.1)	0.72; <.001	0.73 (0.42-0.89)	7.6	54.5	21.0

Note: Pearson CC with significance (*P* value).
Abbreviations: CC, coefficient of correlation; CI, confidence interval; CV, coefficient of variation; EMG, electromyography; ICC, intraclass-correlation coefficient; MDC, minimal detectable change; MVC, maximal voluntary contraction.

coefficient and the ICC (random effect model, single-measure reproducibility) were selected for this study. Based on Shrout,[18] the ICC intervals were chosen as follows: (a) <0.00 to 0.10, virtually no reproducibility; (b) 0.11 to 0.40, slight reproducibility; (c) 0.41 to 0.60, fair reproducibility; (d) 0.61 to 0.80, moderate reproducibility; (e) 0.81 to 1.0, substantial reproducibility.

2.7 | Absolute reliability

The absolute reproducibility measures the degree to which repeated measurements vary and was assessed for all parameters.[17,18] To analyze the absolute reproducibility of the SEM, the coefficient of variation and the minimal detectable change (MDC) were calculated (see Formula 1, 2 and 3). Bland-Alt man plots were also generated.

$$\mathrm{SEM} = \mathrm{SD} \times \sqrt{1 - ICC} \tag{1}$$

$$CV = \frac{\mathrm{SD}}{MW} \times 100. \tag{2}$$

The MDC represents the smallest deviation that can be expected:

$$MDC = \mathrm{SEM} \times 1.96 \times \sqrt{2}. \tag{3}$$

All statistical analyses were performed using SPSS Statistics for Windows (Version 21.0, Released 2012; IBM Corp, Armonk, NY). The levels of significance were set at $P < .05$ (significant), $P < .01$ (highly significant), and $P < .001$ (most significant).

3 | RESULTS

3.1 | Intrasession reliability

The data of the intrasession reliability were substantial reproducible (ICC: 0.93-0.97; CC: 0.81-0.91) for EMG_{max}, $EMG_{A0.5}$., and $EMG_{A2\text{-}4}$ (Table 1).

3.2 | Intraday reliability

The data were normally distributed. The EMG_{max}, $EMG_{A0.5}$, and $EMG_{A2\text{-}4}$ values revealed moderate reliability for a relative (Table 2) and absolute reliabilities, respectively (Figure 1A).

TABLE 3 Interday reliability from MVC of vaginal surface EMG (relative and absolute statistical variables of the parameters): maximal EMG amplitude (EMG_{max}), 0.5 second round maximal EMG amplitude ($EMG_{A0.5}$), and 2 to 4 seconds round maximal EMG amplitude ($EMG_{A2\text{-}4}$)

Parameter	M (±SD), µV	CC; P value	ICC (95% CI)	SEM	CV (%)	MDC
EMG_{max}	46.4 (±18.2) 44.8 (±18.7)	0.47; 0.018	0.48 (0.04-0.77)	13.3	40.5	36.9
$EMG_{A0.5}$	32.1 (±14.5) 31.0 (±15.9)	0.50; <.013	0.51 (0.07-0.78)	7.6	48.1	21.1
$EMG_{A2\text{-}4}$	26.6 (±15.0) 25.3 (±14.2)	0.64; <.001	0.65 (0.28-0.85)	8.7	56.4	24.0

Note: Pearson CC with significance (*P* value).
Abbreviations: CC, coefficient of correlation; ICC (95% CI), CI, confidence interval; CV, coefficient of variation; EMG, electromyography; ICC, intraclass-correlation coefficient; MDC, minimal detectable change.

TABLE 4 Comparison of a reliability study of vaginal sEMG from Auchincloss and McLean[9] (n = 10) with the present study (n = 19)

	Auchincloss and McLean[9] (n = 10)	Present study (2016) (n = 19)
Age (y) MW (±SD)	30 (±3.9)	25 (±2.9)
Measurement position	Supine position, knee angle ca. 90°	
Probe		
Intraday measurements: maximal EMG amplitudes		
M (±SD), μV	k. A.	45.6 (±17.6)
CC; *P* wert	k. A.	0.74; <.001
ICC (95% CI)	0.72 (0.40-0.91)	0.75 (0.45-0.90)
CV (%)	14.2	38.5
SEM	k. A.	8.8
Interday measurements: maximal EMG amplitudes		
M (±SD), μV	16.1 (±13.8)	45.6 (±18.5)
CC; *P* wert	0.46; .01	0.47; .018
ICC (95% CI)	0.41 (0.06-0.66)	0.48 (0.04-0.77)
CV (%)	14.1-15.2	40.5
SEM	15.1	13.3

Note: Measurement position; probe; statistical variables of the maximal EMG amplitude: mean, standard deviation (μV), CC with significance (*P* value).
Abbreviations: CC, coefficient of correlation; CI, confidence interval; CV, coefficient of variation; EMG, electromyography; ICC, intraclass-correlation coefficient.

3.3 | Interday reliability

Fair reproducibility was observed for EMG_{max} and $EMG_{A0.5.}$ However, for EMG_{A2-4}, we found moderate reproducibility (Table 3). The absolute interday reliability revealed moderate reproducibility for all parameters (Figure 1B).

3.4 | Menstruation groups

During interday measurements, participants were either in the proliferation (n = 9) or the secretion (n = 10) group. However, during the third experiment, the participants belonged to either the secretion group (n = 9) or the ischemia group (n = 10). All data regarding menstruation groups were normally distributed except for the parameter T3 $EMG_{A0.5}$. The Student *t* test did not reveal any significant differences between the groups for all parameters (P = .105-.951).

4 | DISCUSSION

This is the first study evaluating the intrasession, intraday, and interday reliabilities of different sEMG parameters using a probe with circumferential electrode-position. Based on the ICC we observed the highest values for the intrasession reliability and the lowest values for the interday reliability while the intraday reliability was in-between. Overall, the parameter EMG_{A2-4} was the most reliable parameter; it revealed substantial reliability for the intrasession measurements and moderate reliability for both the intraday and interday measurements. However, the other two parameters (EMG_{max} and $EMG_{A0.5}$) showed substantial reliability for intrasession measurements, moderate reliability for the intraday measurements, and only fair reliability for the interday measurements. Thus, the use of EMG_{A2-4} may be preferable for long-term studies (eg, training or therapy).

4.1 | Reliability of probes in either the longitudinal or circumferential electrode positions

In the present study, the reliability was analyzed using a probe with circumferential electrode-position. However, studies reported in the literature analyzed the reliability of probes located with longitudinal electrode-position. The difference of the longitudinal position to the circumferential position (as used in the present study) is that the propagation of the action potential is measured perpendicular to the probe, and thus different results were expected.

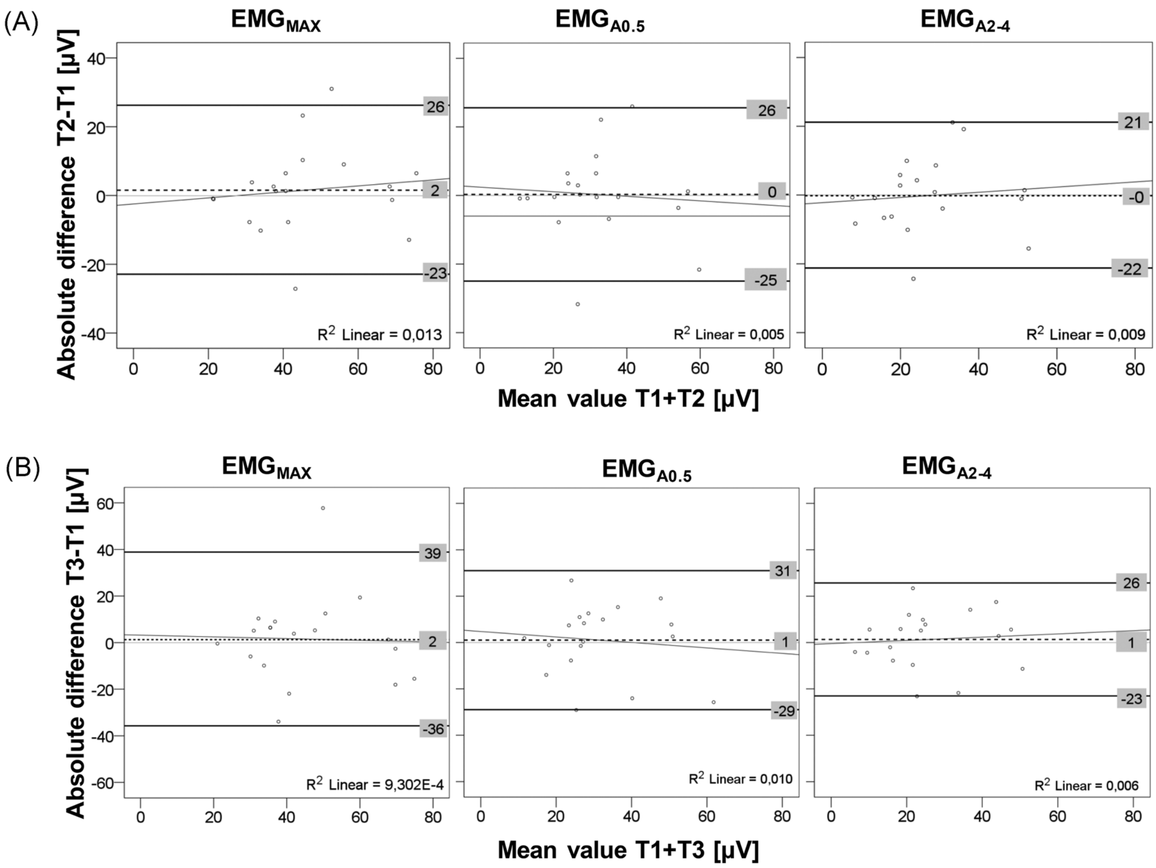

FIGURE 1 Bland-Altman plot (A: intraday reliability, B: interday reliability) differences (A: measurement T1-measurement T2; B: measurement T1-measurement T3 versus mean of the two measurements for 1 maximal EMG amplitude score while MVC EMG_{max}, 2) average A0.5 second round maximal EMG amplitude (EMGA0.5 and 3) A2-4 seconds round maximal EMG amplitude (EMGA2-4) (n = 19). Legend: The lowest and highest horizontal lines represent the 95% limits of agreements (lower limit, upper limit), the middle dashed line symbolizes the mean of the differences between T1 and T3 (systematic bias). The regression line is plotted and the coefficient of determination (R2) is shown. EMG, electromyography; MVC, maximal voluntary contraction

The study described by Auchincloss and McLean[9] is similar to the present study. They examined a similar group, used the same measurement position, and implemented similar calculation methods. They reported moderate to substantial reliability for intrasession measurements, which is comparable to our results. These results were confirmed by König et al[7] Interestingly, according to our study, they observed high SEM and MDC values compared to our study. Thus, it can be concluded that the results of the intrasession reliability do not seem to depend on the electrode-position.

With respect to the intraday reliability, Grape et al[10] reported substantial reliability for the parameters average activity (ICC = 0.94, coefficient of variation [CV] = 11.1%) and peak activity (ICC = 0.90, CV = 14.3%). The study design was similar to our study; however, the contraction time was different. The subjects in the present study performed the MVC for 5 seconds, whereas the subjects in the study of Grape et al[10] performed the MVC for 10 seconds. The parameter peak activity was similar to our calculated EMG_{max}, but they calculated the mean activity over 10 seconds, while we calculated it between the 2nd and the 4th-second during MVC. However, we observed only moderate reliability for $EMG_{A2\text{-}4}$ (ICC = 0.73, CV = 54.5%) and EMG_{max} (ICC = 0.75, CV = 38.5%), respectively. Furthermore, the present study showed fair to moderate reliability for interday measurements. Similar results were reported by Auchincloss and McLean[9] (Table 4). However, Grape et al[10] reported substantial reliability for interday measurements. This difference might result from the time between the test days. Grape et al[10] repeated their measurements 26 to 30 days after the first measurements whereas the measurements were about 1 week apart in the study of Auchincloss and McLean[9] and in the present study. Thus, it can be concluded that the electrode arrangement (longitudinal vs circumferential) has no effect on the reliability of sEMG data. Furthermore, the menstruation cycle seems to have an impact on sEMG interday reliability.

4.2 | Influence of hormones

In the present study, experiments were performed while participants were in different phases of menstruation, which might affect the sEMG reliability. It is known that hormones or body temperature change during menstruation.[19] During the proliferation phase, estrogen- and follicle-stimulating hormone production is increased and influences skin properties.[20] In this phase, the cervical mucus is more liquid. During the secretion phase, the production of progesterone, luteinizing hormone, and gestagen is increased. This leads to decreases in the storage of water within the cervical mucus, and the basal body temperature increases around 0.4°C.[21] Although there were no sEMG differences between the phases, this does not mean that hormones could affect the interday reliability.

In summary, hormones affect muscle perfusion, skin properties, and body temperature, which might influence the sEMG signal (eg, electrical conductivity, the electrical resistance of tissues) and thus the interday reliability—in particular, when the pretest and posttest are not in the same phase of menstruation. It is therefore recommended to consider the menstruation phases when scheduling experiments (pretest and posttest).

4.3 | Evaluation of parameters for clinical trials with vaginal sEMG

Reliable sEMG data play a decisive role in clinical trial studies. They should represent a low source of error. Two interventional studies that used vaginal sEMG were reviewed to compare the results[22,23] and to discuss the measurement variances that might limit the use of vaginal sEMG.

Dannecker et al[23] examined the effects of sEMG on biofeedback training for three to 6 months. The patients were postmenopausal and premenopausal women with stress incontinence (first to third degree) as well as mixed incontinence. During the training intervention, maximal EMG of PFM increased from $11.3 \pm 6.1\,\mu V$ (pretest) to $22.0 \pm 16.5\,\mu V$ (posttest) and 11% of patients were cured. To compare these results with the present study, the parameter $EMG_{A2\text{-}4}$ was used. The training effect of the intervention was 51%. It could be determined a CV from 55% in the present study. The measurement errors exceeded the intervention effects. The same was determined by Batista et al[22] during biofeedback training with a training effect of 36%. The mean EMG amplitude was collected as an MVC parameter. As measured by the natural measurement errors from the present study, the EMG amplitude was higher than the effect of training. The effect of both interventions was comparable to the natural measurement errors of the vaginal sEMG.

One study suggested to include the measurement error when evaluating training effects by calculating the SEM means from reliability studies.[24] The analyses will take place for each individual. Evaluation of therapies has advantages: both methodical deviations and individual variance were considered.

4.4 | Limitations of the study

The main limitation of the study is that vaginal lubrication and body temperatures were not measured in the experiments. Lubrication in healthy women can vary between 2 and 5 mL vaginal secretions.[25] However, we tried to standardize vaginal lubrication using 5 mL of water-soluble lubricant before inserting the probe. Furthermore, due to the electrode configuration, different PFM values were measured, and EMG crosstalk from the transverses abdominus and oblicuus internus cannot be ruled out.

5 | CONCLUSION

This study showed substantial reliability for intrasession measurements and moderate reliability for intraday measurements. The interday measurements revealed fair to moderate reliability values. The parameter with the highest reliability values was $EMG_{A2\text{-}4}$. Therefore, this parameter can be recommended for further analysis.

In this study, a probe in the circumferential electrode-position was used. The results are similar to those reported in the literature using probes in a longitudinal electrode-position. Based on the reliability data, there is no difference between probes in either the circumferential and longitudinal electrode-position. The interday reliability was only fair to moderate in this study.

The menstruation cycle likely impacts the reliability and thus should be considered in future interventional studies, such as training or physiotherapeutic studies.

ACKNOWLEDGMENTS

We are grateful to *TIC Medizintechnik GmbH*, which produces and provided the EMG System Syntic (incl. the bipolar vaginal probe ti1020) to perform the experiments. No further sources of funding were used to assist this study. The authors have no conflicts of interest that are directly relevant to the content of this study. All authors were fully involved in the study and in the preparation of the manuscript.

ETHICS STATEMENT

The study has been approved by the ethics committee (ID: 3695-02/13) of the university hospital Jena (Universitätsklinikum Jena) and was conducted in accordance with the latest declaration of Helsinki. The data were conducted at the institute of physiotherapy (university hospital Jena).

ORCID

Ronja Scharschmidt http://orcid.org/0000-0002-8131-2393

REFERENCES

1. Pereira LC, Botelho S, Marques J, et al. Electromyographic pelvic floor activity: Is there impact during the female life cycle? *Neurourol Urodyn*. 2016;35(2):230–234. https://doi.org/10.1002/nau.22703
2. Burti JS, Hacad CR, Zambon JP, Polessi EA, Almeida FG. Is there any difference in pelvic floor muscles performance between continent and incontinent women? *Neurourol Urodyn*. 2015;34(6):544–548. https://doi.org/10.1002/nau.22613
3. Enck P, Vodušek DB. Electromyography of pelvic floor muscles. *J Electromyogr Kinesiol*. 2006;16(6):568–577. https://doi.org/10.1016/j.jelekin.2006.08.007
4. Auchincloss C, McLean L. Does the presence of a vaginal probe alter pelvic floor muscle activation in young, continent women? *J Electromyogr Kinesiol*. 2012;22(6):1003–1009. https://doi.org/10.1016/j.jelekin.2012.06.006
5. Johnson VY. Effects of a submaximal exercise protocol to recondition the pelvic floor musculature. *Nurs Res*. 2001;50(1):33–41.
6. Yang JF, Winter DA. Electromyography reliability in maximal and submaximal isometric contractions. *Arch Phys Med Rehabil*. 1983;64(9):417–420.
7. Koenig I, Luginbuehl H, Radlinger L. Reliability of pelvic floor muscle electromyography tested on healthy women and women with pelvic floor muscle dysfunction. *Ann Phys Rehabil Med*. 2017;60:382–386. https://doi.org/10.1016/j.rehab.2017.04.002
8. Luginbuehl H, Naeff R, Zahnd A, Baeyens J-P, Kuhn A, Radlinger L. Pelvic floor muscle electromyography during different running speeds: An exploratory and reliability study. *Arch Gynecol Obstet*. 2016;293(1):117–124. https://doi.org/10.1007/s00404-015-3816-9
9. Auchincloss CC, McLean L. The reliability of surface EMG recorded from the pelvic floor muscles. *J Neurosci Methods*. 2009;182(1):85–96. https://doi.org/10.1016/j.jneumeth.2009.05.027
10. Grape HH, Dedering Å, Jonasson AF. Retest reliability of surface electromyography on the pelvic floor muscles. *Neurourol Urodyn*. 2009;28(5):395–399. https://doi.org/10.1002/nau.20648
11. Glazer HI, Jantos M, Hartmann EH, Swencionis C. Electromyographic comparisons of the pelvic floor in women with dysesthetic vulvodynia and asymptomatic women. *J Reprod Med*. 1998;43(11):959–962.
12. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine:. *Sports Med*. 1998;26(4):217–238.
13. Bates BT, Zhang S, Dufek JS, Chen FC. The effects of sample size and variability on the correlation coefficient. *Med Sci Sports Exerc*. 1996;28(3):386–391.
14. Keshwani N, McLean L. State of the art review: intravaginal probes for recording electromyography from the pelvic floor muscles. *Neurourol Urodyn*. 2015;34(2):104–112.
15. Thorp JM JR, Bowes WA J.r, Droegemueller W, Wicker H. Assessment of perineal floor function: electromyography with acrylic plug surface electrodes in nulliparous women. *Obstet Gynecol*. 1991;78(1):89–92.
16. Baeßler K, Junginger B. Beckenboden-Fragebogen für Frauen. *Aktuelle Urol*. 2011;42(5):316–322. https://doi.org/10.1055/s-0031-1271544
17. Baumgarter TA. Norm-referenced measurement: reliability. In: Safrit MJ, Wood TM, eds. *Measurement Concepts in Physical Education and Exercise Science*. Champaign (IL): Human Kinetics; 1989:45–72.
18. Shrout PE. Measurement reliability and agreement in psychiatry. *Stat Methods Med Res*. 1998;7(3):301–317. https://doi.org/10.1177/096228029800700306
19. Janse de Jonge XAK. Effects of the menstrual cycle on exercise performance. *Sports Med*. 2003;33(11):833–851. https://doi.org/10.2165/00007256-200333110-00004
20. Stricker R, Eberhart R, Chevailler M-C, Quinn FA, Bischof P, Stricker R. Establishment of detailed reference values for luteinizing hormone, follicle stimulating hormone, estradiol, and progesterone during different phases of the menstrual cycle on the Abbott ARCHITECT analyzer. *Clin Chem Lab Med*. 2006;44(7):883–887. https://doi.org/10.1515/CCLM.2006.160
21. Stephenson LA, Kolka MA. Menstrual cycle phase and time of day alter reference signal controlling arm blood flow and sweating. *Am J Physiol*. 1985;249(2 pt 2):R186–R191. https://doi.org/10.1152/ajpregu.1985.249.2.R186
22. Batista RLA, Franco MM, Naldoni LMV, Duarte G, Oliveira AS, Ferreira CHJ. Biofeedback and the electromyographic activity of pelvic floor muscles in pregnant women. *Rev Bras Fisioter*. 2011;15(5):386–392.
23. Dannecker C, Wolf V, Raab R, Hepp H, Anthuber C. EMG-biofeedback assisted pelvic floor muscle training is an effective therapy of stress urinary or mixed incontinence: a 7-year experience with 390 patients. *Arch Gynecol Obstet*. 2005;273(2):93–97. https://doi.org/10.1007/s00404-005-0011-4
24. Hopkins WG. A spreadsheet for monitoring an individual's changes and trend. *Sportscience*. 2017;21(5-9):10.
25. Huggins GR, Preti G. Vaginal odors and secretions. *Clin Obstet Gynecol*. 1981;24(2):355–377.

How to cite this article: Scharschmidt R, Derlien S, Siebert T, Herbsleb M, Stutzig N. Intraday and interday reliability of pelvic floor muscles electromyography in continent woman. *Neurourol Urodyn*. 2019;1–8. https://doi.org/10.1002/nau.24187