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ORIGINAL RESEARCH

Validity and Short-Term Repeatability of a Novel Hand-Held Respiratory Health Meter for the Assessment of Dynamic Maximal Respiratory Pressures in Healthy Young Adults

Herkko Ryynänen[1,2], Anssi Sovijärvi[3], Ilpo Kuronen[4], Essi K Ahokas[1], Maarit Valtonen[5], Johanna K Ihalainen[1], Juhani Multanen[1,6]

[1]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland; [2]Finnish Lung Health Association, Helsinki, Finland; [3]Department of Clinical Physiology, University of Helsinki, Helsinki, Finland; [4]Reagena Ltd., Toivala, Finland; [5]Finnish Institute of High Performance Sport KIHU, Jyväskylä, Finland; [6]South-Eastern Finland University of Applied Sciences, Savonlinna, Finland

Correspondence: Herkko Ryynänen, Faculty of Sport and Health Sciences, University of Jyväskylä, PO Box 35, Jyväskylä, Finland, Tel +358 40 7030231, Email herkko.ryynanen@gmail.com

Purpose: Measuring maximal airway pressure is an essential part of the assessment of respiratory functions. Portable handheld devices have made clinical measurements more available, but reliable and user-friendly devices for non-clinical use remain rare. This study sought to determine the validity and short-term repeatability of measurements of dynamic maximal inspiratory pressure (dMIP) and dynamic maximal expiratory pressure (dMEP) by using a novel self-administered respiratory health meter (WellO2-RHM) in asymptomatic young adults.

Patients and Methods: dMIP and dMEP were measured with WellO2-RHM in asymptomatic adult volunteers (n=26, 15 male and 11 female, age 26–41 years). These values were compared with quasi-static maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) obtained from the same volunteers using another respiratory manometer (MicroRPM). The measurements of dMIP and dMEP with WellO2-RHM were repeated in the same individuals at an interval of one week for assessment of their short-term repeatability.

Results: The Pearson correlation coefficients of dMIP and dMEP values with MIP and MEP values were high ($r=0.840$, $p<0.001$; $r=0.849$, $p<0.001$, respectively). The dMIP and dMEP values were consistently lower than the quasi-static MIP and MEP values in the same individuals. The short-term repeatability of the dMIP and dMEP in one week interval proved to be moderately good in terms of the coefficient of variation (CV), the intraclass correlation coefficient (ICC), the standard error of measurement (SEm) and minimal detectable change (MDC) (10.0%, 0.825, $p<0.001$, 7 cmH2O and 20 cmH2O and 9.1%, 0.895, $p<0.001$, 12 cmH2O and 34 cmH2O, respectively).

Conclusion: The results indicate that the WellO2-RHM is a valid and repeatable method for the assessment of dMIP and dMEP in asymptomatic young adults, but the absolute values are lower than those obtained with devices measuring quasi-static MIP and MEP. The findings suggest that WellO2-RHM can be used for self-monitoring of the effects of respiratory muscle training in healthy young adults.

Keywords: breathing, respiratory muscles, assessment, maximal airway pressures, short-term repeatability

Introduction

Breathing demands continuous work from the respiratory muscles. The force produced by these muscles may be compromised in individuals with neuromuscular or lung diseases, postsurgical complications,[1] or prolonged mechanical ventilation.[2] This can lead to ineffective breathing and altered lung function, impairing health, physical performance, and quality of life.[3] Evaluating respiratory muscle strength is therefore an essential component of respiratory system assessment.[4] The force produced by the inspiratory and expiratory muscles is measured as the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). Measurement of maximal respiratory pressure can aid in detecting respiratory muscle weakness, diagnosing diseases,[5] and monitoring the effectiveness of respiratory muscle training or pulmonary rehabilitation.[1]

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Inspiratory muscle training (IMT) has been included in pulmonary rehabilitation programs, as it has been shown to decrease dyspnea and to improve exercise capacity and quality of life in patients with chronic obstructive pulmonary disease (COPD).[6] IMT has also been shown to improve pulmonary function, dyspnea, physical performance, and quality of life after acute COVID-19,[7] and breathlessness after post-acute COVID-19.[8] Hence, respiratory muscle training (RMT) is one of the most feasible and independently executable rehabilitative strategies for patients recovering from COVID-19. Furthermore, the RMT could also be a useful training modality for improving exercise performance in athletes,[9] and healthy individuals.[10] The regular assessment of respiratory muscle strength during training period enables training monitoring and progression, as individual intensity and training resistance are usually based on maximal respiratory pressures.

Currently, several methods and devices are available for measuring maximal respiratory pressure.[4] Portable devices have become more common because they have been shown to be valid, reliable, mobile, noninvasive, and easy to use.[1,4,5] However, such devices are typically designed for clinical use, leaving an unmet need for reliable and self-administered devices for assessing respiratory muscle strength and self-monitoring rehabilitation or training.

Traditionally, maximal respiratory pressure is measured as static or quasi-static (Müller maneuver), as the use of devices with minimal airflow (air leak diameter of 2 mm) through devices during measurement is recommended by the American Thoracic Society (ATS) and European Respiratory Society (ERS).[4,11] This enables the ability to build higher pressures against an almost totally occluded airway.[4] However, this procedure requires unusual breathing effort compared to the demands of everyday life. Dynamic measurements of these maximal respiratory pressures could be more practical, as they mimic normal breathing patterns and pulmonary function. A novel self-administered respiratory health meter was developed (WellO2-RHM; WellO2 Ltd., Kiuruvesi, Finland) for use in conjunction with the WellO2-respiratory training device (WellO2 Ltd., Kiuruvesi, Finland). The WellO2-RHM device is equipped with a semi-open airway, which allows for dynamic measurement with lower resistance and higher airflow, resulting in a lower obtained peak pressure. Moreover, the time–pressure curves differ between these two methods. Even though these methods express different aspects of respiratory muscle contraction during maximal breathing efforts, it is important for validation to investigate association between these two methods. The safety of the WellO2-respiratory training device has been confirmed in a recent clinical study in asthma patients,[12] and previously in a pilot study in women with voice symptoms,[13] but the validity and reliability of the WellO2-RHM for measuring respiratory muscle strength has not previously been reported.

This study investigated the measurement validity of the WellO2-RHM device in quantifying dynamic maximal inspiratory pressure (dMIP) and dynamic maximal expiratory pressure (dMEP) in healthy and physically active young adults. Our hypothesis was that the values obtained from dynamic measurements of the WellO2-RHM would have a high correlation with the values from the reference device measuring quasi-static pressures (MicroRPM). A secondary objective was to examine the short-term repeatability of the WellO2-RHM in measuring dMIP and dMEP with an interval of one week.

Materials and Methods

Study Design and Participants

The healthy participants in this cross-sectional study were recruited from among participants in a randomized controlled trial investigating the effects of different intensities of inspiratory muscle training with a WellO2-respiratory training device on respiratory muscle strength, lung function parameters and maximal aerobic fitness (study report in preparation). All the participants were students at the University of Jyväskylä, Finland, or their acquaintances and were recruited through an email advertisement in early 2021. The inclusion criteria were age 18–45 years and regular participation in sports and exercise for at least 2 hours a week. The exclusion criteria were any chronic or acute disease and active smoking status within the past 10 years. Health and activity information related to the inclusion and exclusion criteria was assessed from subjective descriptions of the participants before enrollment.

The Human Sciences Ethics Committee of the University of Jyväskylä approved the study design (749/13.00.04.00/2020), and all study participants provided written informed consent before inclusion. The study followed the principles outlined in the Declaration of Helsinki.

Respiratory Devices

The WellO2-RHM is a portable respiratory manometer compatible with the WellO2-respiratory training device that incorporates tapered flow resistive loading for inhalation and expiration and warm steam production during inhalation (Figure 1). The WellO2-RHM is equipped with pressure and temperature sensors, and it is operated by the WellO2 mobile app via a Bluetooth connection. The WellO2-RHM uses piezo resistive pressure technology and pressure sensors were calibrated during manufacturing using pressure vessel calibration. WellO2-RHM mouthpieces are designed for dynamic measurement of maximal inspiratory and expiratory (dMIP and dMEP) pressures, a similar procedure with another dynamic respiratory manometer,[14] and it can also be applied for respiratory training. The mobile app uses real-time pressure data to visualize breathing efforts (pressure-time curves) and the obtained inspiratory and expiratory peak pressure values are expressed as cmH2O. The device has a wide air leak (diameter of air tubes 5 mm, length 10 mm for inspiration tube and 50 mm for expiration tube), which leads to higher airflow during measurement compared to traditional measurement devices, such as the MicroRPM.

The MicroRPM (Vyaire Medical, Mettawa, Illinois, United States) is a portable respiratory manometer designed for the measurement of maximum inspiratory and expiratory pressure. The values obtained are expressed digitally on the device as cmH2O, and the display uses piezo resistive pressure sensing technology. The MIP and MEP values are averages of 1 second maximum values. The MicroRPM is designed for use with a separate rubber mouthpiece. The device has a small air leak, as recommended by the ATS and ERS,[4] which allows only low airflow during measurement. MicroRPM has been shown to be a reliable tool for assessing respiratory pressure in healthy volunteers.[15]

Measurement Protocol

The participants provided dMIP and dMEP data with WellO2-RHM at two laboratory visits at a mean interval of 6,8 (SD 4,2) days. MIP and MEP data with MicroRPM were provided at the second laboratory visit due to the randomized controlled trial protocol, where participants started respiratory muscle training intervention after MIP and MEP data acquisition. Participants were asked not to perform respiratory muscle training with WellO2 or any other respiratory training device between visits and not to participate in any strenuous activity during the 24 h preceding the visits. Each participant was measured at the same time of day.

During the first visit, the participants warmed for 5 minutes on an ergometer (Monark Ergomedic 839E, Sweden) at a speed of 60–100 rpm with a load of 75 W for men and 50 W for women. After the warm-up, the participants performed maximal inspiratory and expiratory trials with the WellO2-RHM. During the second laboratory visit, after a similar warm-up, the participants performed maximal inspiratory and expiratory trials first with the WellO2-RHM and second with MicroRPM. The order of measurements was not randomized to ensure that the reliability measurements of dMIP and dMEP and that the MIP and MEP data used in randomized controlled trial were not altered by the order of the measurements. Finally, at the same visit, the participants underwent lung function tests with Vyntus ONE (Vyaire Medical, Mettawa, Illinois, United States) to evaluate the normality of their ventilatory function and lung volume (FEV1 and FVC).

Figure 1 The WellO2 respiratory training device and WellO2-RHM mouthpiece separately and when connected.

Both dynamic and quasi-static MIP and MEP measurements were performed similarly and as recommended by the ATS and ERS,[11] i.e., in an upright sitting position, with a nose clip and separate flanged rubber mouthpiece and with at least a 30-second rest between trials to prevent fatigue. Both measurements were performed successively a minimum of three times and a maximum of eight times with each device. Trials were repeated after three successive repetitions if the two highest values were not within 10% of each other and if the last trial resulted in the highest value. A minimum rest interval of 1–2 minutes was allowed between the MIP and MEP measurement sessions with each device. MIP was measured as maximal forced inspiration starting from the residual volume (RV) remaining after maximal expiration, and MEP was measured as maximal forceful expiration starting from total lung capacity (TLC) following maximal inspiration. Participants held the devices with their own hands, closed their lips around the flanged rubber mouthpiece and were instructed to use their other hand to increase the seal between their lips and mouthpiece in both the MIP and MEP trials. A technician provided support for the participants´ cheeks to prevent contraction of the buccal muscles during the MEP trials.

Spirometry was performed as recommended by the ATS and ERS.[16] Lung function was measured following the forced vital capacity (FVC) protocol. Participants performed a minimum of three and a maximum of eight successive trials with a minimum rest interval of 1 minute between trials. The protocol started with restful breathing, followed by slow maximum exhalation down to the RV, forceful maximum inhalation up to the TLC, and explosive exhalation, lasting at least 6 seconds, down to the RV. The participants' highest values were used in the analysis.

In both visits, instructions, and guidance on all the measurements were performed in a structural manner by the same appropriately trained technician.

Statistical Analysis

Descriptive statistics are presented as the means and standard deviations (SD) or as counts with percentages. The normality of variables was evaluated with the Shapiro–Wilk W-test. As the data were normally distributed, the analysis was conducted using parametric statistics. The characteristics of the sexes were compared using a *t* test. The construct validity between the measures of dMIP and dMEP with the WellO2-RHM and MIP and MEP with MicroRPM was calculated by using Pearson´s correlation coefficient. Correlation coefficient below 0.2 is regarded very weak, 0.2–0.39 as weak, 0.40–0.59 as moderate, 0.60–0.79 as strong and 0.8–1 as very strong.[17]

The Bland–Altman method with limits of agreement (LOA) was used to calculate the difference between the two methods, i.e., WellO2-RHM and MicroRPM, and between the first and second measurements performed with the WellO2-RHM. The variability of the results at the individual level was determined using the Bland–Altman method,[18] whereby the differences between two measurements were plotted against the corresponding mean for each subject. Relative short-term repeatability was evaluated with the intraclass correlation coefficient (ICC) with 95% confidence intervals (CIs) calculated using two-way mixed and absolute agreement models. ICC values > 0.75 were considered fair and values > 0.90 were considered excellent.[19] Absolute short-term repeatability was calculated with the coefficient of variation (CV), the standard error of measurement (SEm) and minimal detectable change (MDC). The CV estimates the absolute variation between test and retest measurements, and values <10% are considered adequate.[20] SEm estimates the average effect of measurement error on the results.[20] MDC shows which changes in the results are outside of measurement error, and MDC% < 10% are considered excellent and < 30% considered acceptable.[20] The participants' highest values were used for all analyses, except the Bland–Altman analysis, where the mean of the three highest values was used. The level of significance was set to p<0.05. All the statistical analyses were performed using IBM SPSS 26.0 (IBM Corp., Armonk, NY, USA).

Results

The participants' anthropometric and physiological characteristics are shown in Table 1. All participants had normal lung function, i.e., FVC and FEV1 were above the normal lower limits (z-values of FVC and FEV1 ranged from −0.399 to 2.061 and from −1.356 to 1.249 in men and from −0.675 to 1.521 and from −1.340 to 1.334 in women, respectively), when compared to the reference values for Finnish adults.[21] No sex differences in relative lung function were detected via spirometry (Table 1).

The dMIP and dMEP values measured with WellO2-RHM were systematically and significantly lower than MIP and MEP values measured with MicroRPM (mean dMIP 29 cmH2O lower (p<0.001); mean dMEP 35 cmH2O lower

Table 1 The Anthropometric and Physiological Characteristics of the Participants are Expressed as the Means and SDs

	All	Men	Women	p value
Participants n (%)	26 (100)	15 (58)	11 (42)	
Age (Year)	32 (3.7)	33.1 (3.0)	30.7 (4.2)	0.099
Height (cm)	173 (8)	177 (6)	167 (6)	<0.001
Weight (kg)	72.9 (12.7)	80.3 (9.8)	63.0 (8.8)	<0.001
BMI (kg/m²)	24.3 (2.9)	25.5 (2.4)	22.6 (2.8)	0.008
VC (l)	5.4 (1.1)	6.2 (0.80)	4.4 (0.5)	<0.001
VC of predicted (%)	108.6 (8.7)	109.5 (9.1)	104.8 (8.5)	0.191
FVC (l)	5.3 (1.2)	6.1 (0.8)	4.3 (0.5)	<0.001
FVC of predicted (%)	107.4 (8.9)	113.3 (8.7)	106.7 (8.0)	0.062
FEV1 (l)	4.0 (0.8)	4.4 (0.6)	3.4 (0.4)	<0.001
FEV1 of predicted (%)	99.0 (9.3)	100.6 (8.7)	99.2 (9.6)	0.694
FEV1/FVC	0.74 (0.06)	0.73 (0.05)	0.78 (0.07)	0.029
FEV1/FVC of predicted (%)	90.3 (7.3)	88.6 (6.3)	92.7 (8.8)	0.186
PEF (l/s)	9.3 (2.0)	10.4 (1.6)	7.8 (1.3)	<0.001
PEF of predicted (%)	98.8 (15.7)	96.9 (15.0)	101.4 (17.1)	0.482

Note: The values were predicted according to Kainu et al 2016.
Abbreviations: BMI, body mass index; VC, vital capacity; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; FEV1/FVC, ratio of forced expiratory volume in one second to forced vital capacity; PEF, peak expiratory flow.

(p<0.001)) (Table 2). The linear correlations between the measurements of dMIP and MIP and between dMEP and MEP were strong (r=0.840 and r=0.849, respectively) and statistically significant (p<0.001) (Figure 2).

The within-subject difference between the measurements of the dMIP and MIP obtained with WellO2-RHM and MicroRPM were almost all within the 95% limits of agreement (Figure 3A). Similarly, the within-subject difference between the measurements of the dMEP and MEP obtained with WellO2-RHM and MicroRPM were almost all within the 95% limits of agreement (Figure 3B).

Table 2 The Dynamic and Quasi-Static Maximal Inspiratory and Expiratory Pressures Measured with the WellO2-RHM and MicroRPM are Expressed as the Means and SDs

		All (n=26)	Male (n=15)	Female (n=11)	p value
1st visit					
WellO2-RHM					
dMIP (cmH2O)	Best	102 (17)	110 (16)	90 (12)	0.003
	Mean	99 (17)	107 (16)	88 (13)	0.003
dMEP (cmH2O)	Best	182 (38)	201 (32)	155 (27)	0.001
	Mean	174 (37)	193 (30)	148 (28)	0.002
2nd visit					
WellO2-RHM					
dMIP (cmH2O)	Best	103 (19)	111 (15)	92 (17)	0.005
	Mean	99 (18)	107 (16)	89 (17)	0.008
dMEP (cmH2O)	Best	184 (41)	205 (32)	155 (35)	0.001
	Mean	178 (41)	199 (32)	148 (33)	0.001
MicroRPM					
MIP (cmH2O)	Best	133 (25)	146 (23)	117 (19)	0.002
	Mean	129 (25)	142 (23)	112 (18)	0.001
MEP (cmH2O)	Best	220 (49)	249 (30)	180 (42)	<0.001
	Mean	213 (49)	241 (33)	175 (43)	<0.001

Abbreviations: dMIP, dynamic maximal inspiratory pressure; dMEP, dynamic maximal expiratory pressure; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure; Best, highest value obtained; Mean, mean of 3 highest values obtained.

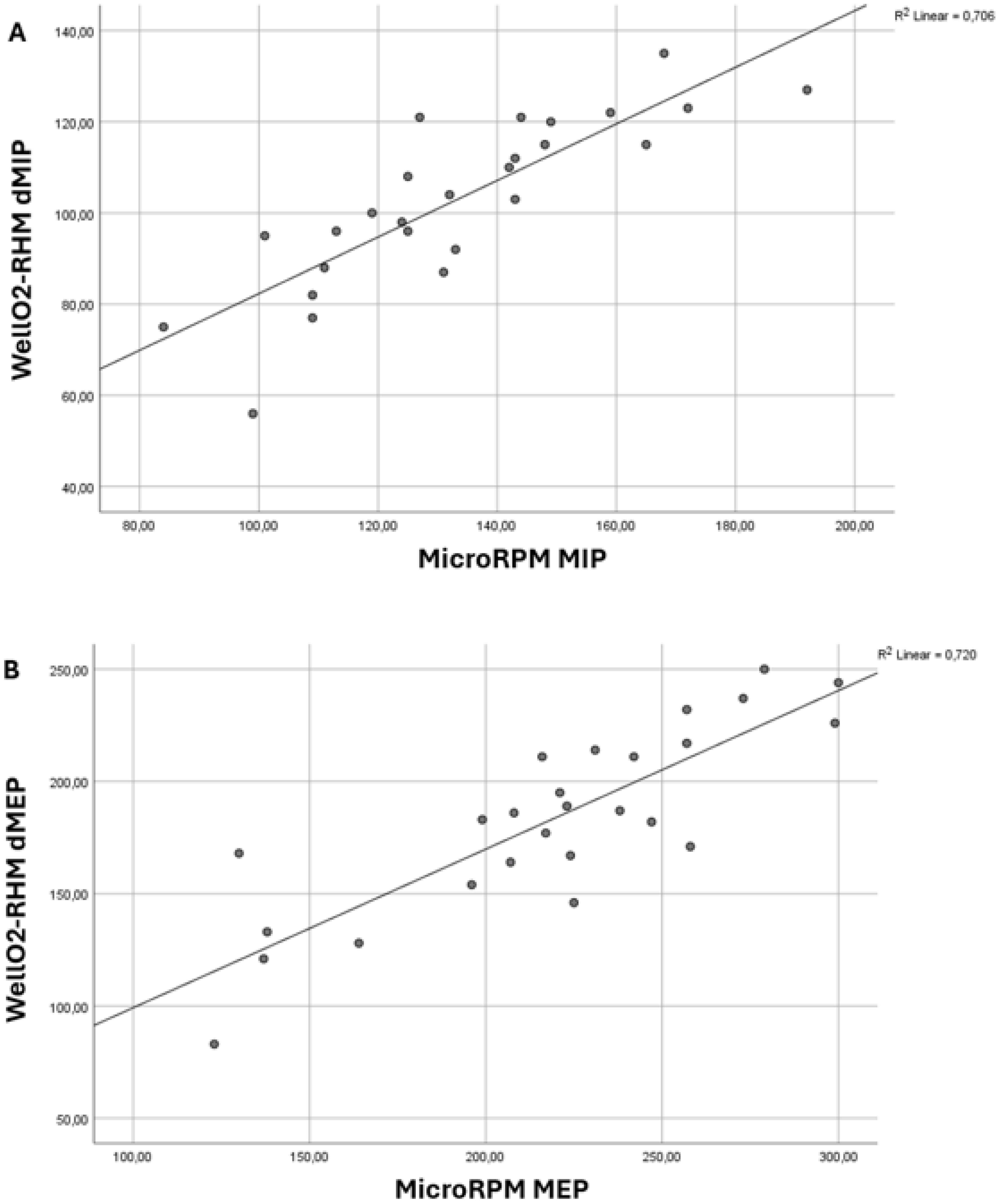

Figure 2 Scatterplot showing individual measurements of dMIP and MIP (**A**) and dMEP and MEP (**B**) with WellO2-RHM and MicroRPM. Best-fit linear regression line shows linear relationship between measurements with two devices.

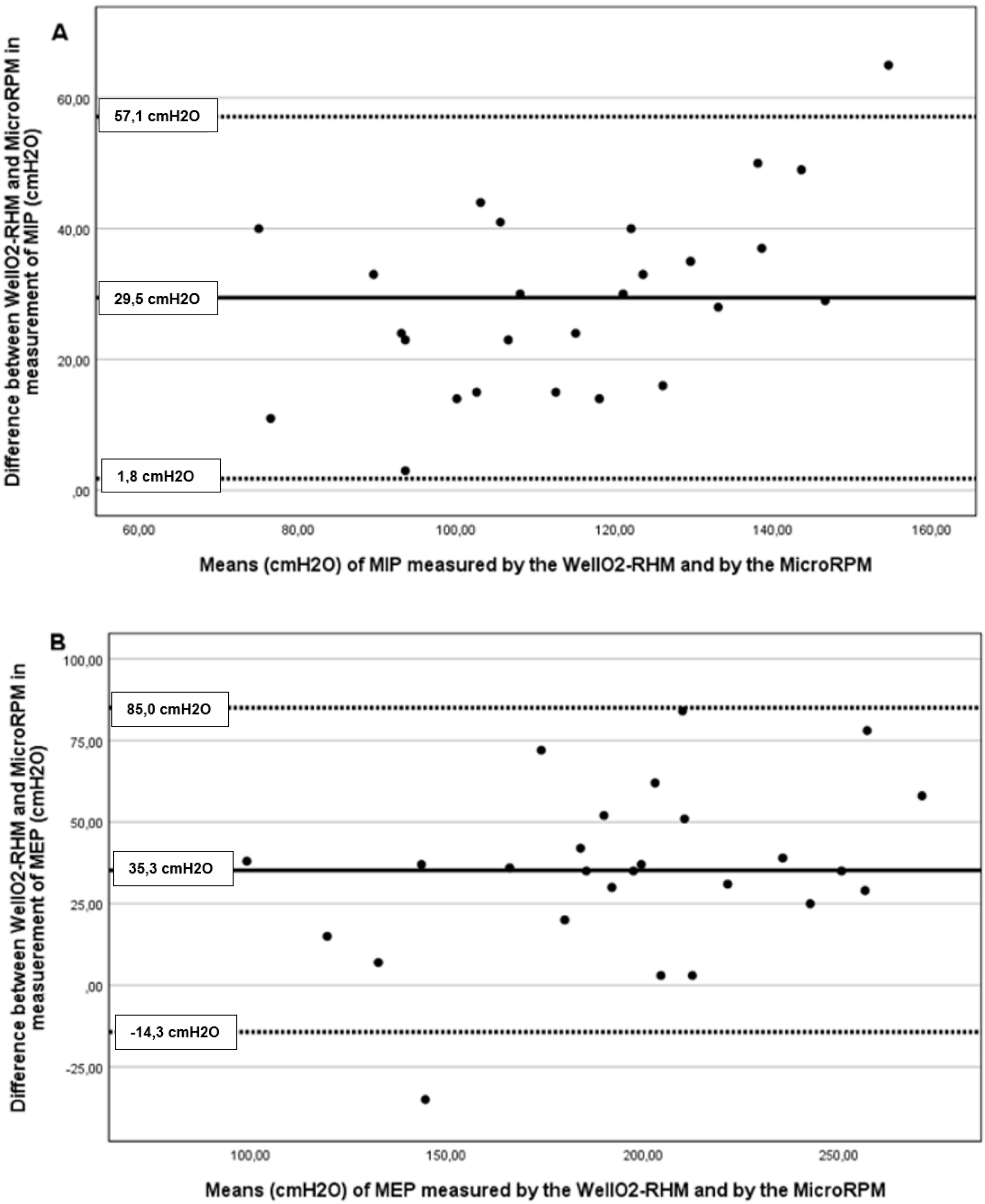

Figure 3 Differences between the MicroRPM and WellO2-RHM (MicroRPM – WellO2-RHM) in measurements of the dynamic and quasi-static MIP (**A**) and dynamic and quasi-static MEP (**B**), plotted against the mean for each participant. The dotted line shows the 95% limit of agreement.

For the short-term repeatability measurements of dMIP with WellO2-RHM, the values of the intersession CV, ICC, SEm and MDC were 10.0%, 0.825 (95% CI 0.631–0.921, p<0.001), 7.22 cmH2O and 20.01 cmH2O. For the similar short-term repeatability measurements of dMEP with WellO2-RHM, the values of the intersession CV, ICC, SEm and MDC were 9.1%, 0.895 (95% CI 0.774–0.953, p<0.001), 12.19 cmH2O and 33.78 cmH2O. The ICC values and 95% confidence intervals showed that short-term repeatability varied between fair and excellent for the dMIP, and between good and excellent for the dMEP measurements. The SEm and MDC values for both the dMIP and dMEP were reasonably low. The dMIP and dMEP values obtained at the second visit with the WellO2-RHM were slightly greater than those at the first visit, but the differences were not statistically significant (p=0.073–0.158) (Table 2).

Figure 4 shows the Bland–Altman plot for the 95% limits of agreement between the first and second measurements of the dMIP and dMEP with WellO2-RHM. In terms of individual variability, the limits of agreement were rather broad for both dMIP and dMEP measurements (37 cmH2O and 73 cmH2O, respectively), and especially for the dMEP.

Discussion

This study aimed to determine the validity and short-term repeatability of assessments of dynamic maximal respiratory pressure obtained using the WellO2-RHM device in healthy and physically active young adults. We found a high correlation between the dMIP and dMEP values measured with the WellO2-RHM method and the MIP and MEP values measured with the MicroRPM method. We also found that the short-term repeatability of dMIP and dMEP values obtained with WellO2-RHM were reasonable. These results suggest that the WellO2-RHM may be a suitable device for self-assessing maximal respiratory pressures in healthy and physically active young adults and hence also for self-monitoring of individual respiratory training effects.

Maximal respiratory pressure is dependent not only on individual characteristics such as age and gender but also on subjects' cooperation and motivation and on the measurement protocol and equipment used.[1,22] We found that the maximal respiratory pressure values measured with the WellO2-RHM were systematically and significantly lower than those measured with the MicroRPM. This difference between the traditional (static) and the new (dynamic) method was expected, as the WellO2-RHM has wider air leak than the MicroRPM. A wider air leak has previously been shown to yield lower maximal pressure values, as was observed in our results.[22,23] Despite the difference in absolute values of maximal respiratory pressures between the methods, dMIP and MIP, as well as dMEP and MEP showed good mutual correlation in the present study, as already shown in previous studies comparing static and dynamic methods.[24,25] The ICC confidence intervals indicate fair to excellent repeatability of the dynamic maximal pressures, with the dMEP showing slightly better repeatability than the dMIP. The same trend was observed for the CV, where both values were within an acceptable 10%.[20] The SEm and MDC values were < 7% and < 30%, respectively, of both the dMIP and dMEP measurements with WellO2-RHM, indicating reasonable measurement error and minimal detectable change. Lower CV, SEm and MDC values suggest better test-retest reliability.[26] The limits of agreement between 1st and 2nd measurement with WellO2-RHM were narrower than those between measurements with wellO2-RHM and MicroRPM. This indicates good measurement accuracy. The ICC and SEm values and limits of agreement for the dMIP and dMEP measurements with WellO2-RHM were also of the same magnitude as for the MIP and MEP values previously found with MicroRPM.[15] Thus, the short-term repeatability of the devices seems to be quite similar.

Although the MicroRPM values in this study were systematically greater than the WellO2-RHM values, the good measurement repeatability of the WellO2-RHM suggests that it is a reliable device for self-monitoring of individual training effects among healthy young adults.

Since maximal respiratory trials are rarely used in real life, warm-up and learning effects may impact the results.[27] Inspiratory muscle warm-up has been shown to increase inspiratory muscle strength,[28] and to reduce the number of trials needed to reach the maximal values compared to sham warm-up,[14] and to attenuate the learning effect (i.e., decreasing the variability in maximal respiratory pressure) during repeated maximal inspiratory trials in the same session.[29] Here, the dMIP and dMEP measurements were both conducted first with the WellO2-RHM. Thus, in the protocol measurements with WellO2-RHM may have served as a warm-up exercise for the respiratory muscles before the MicroRPM measurements, where the highest individual values were produced in fewer trials.

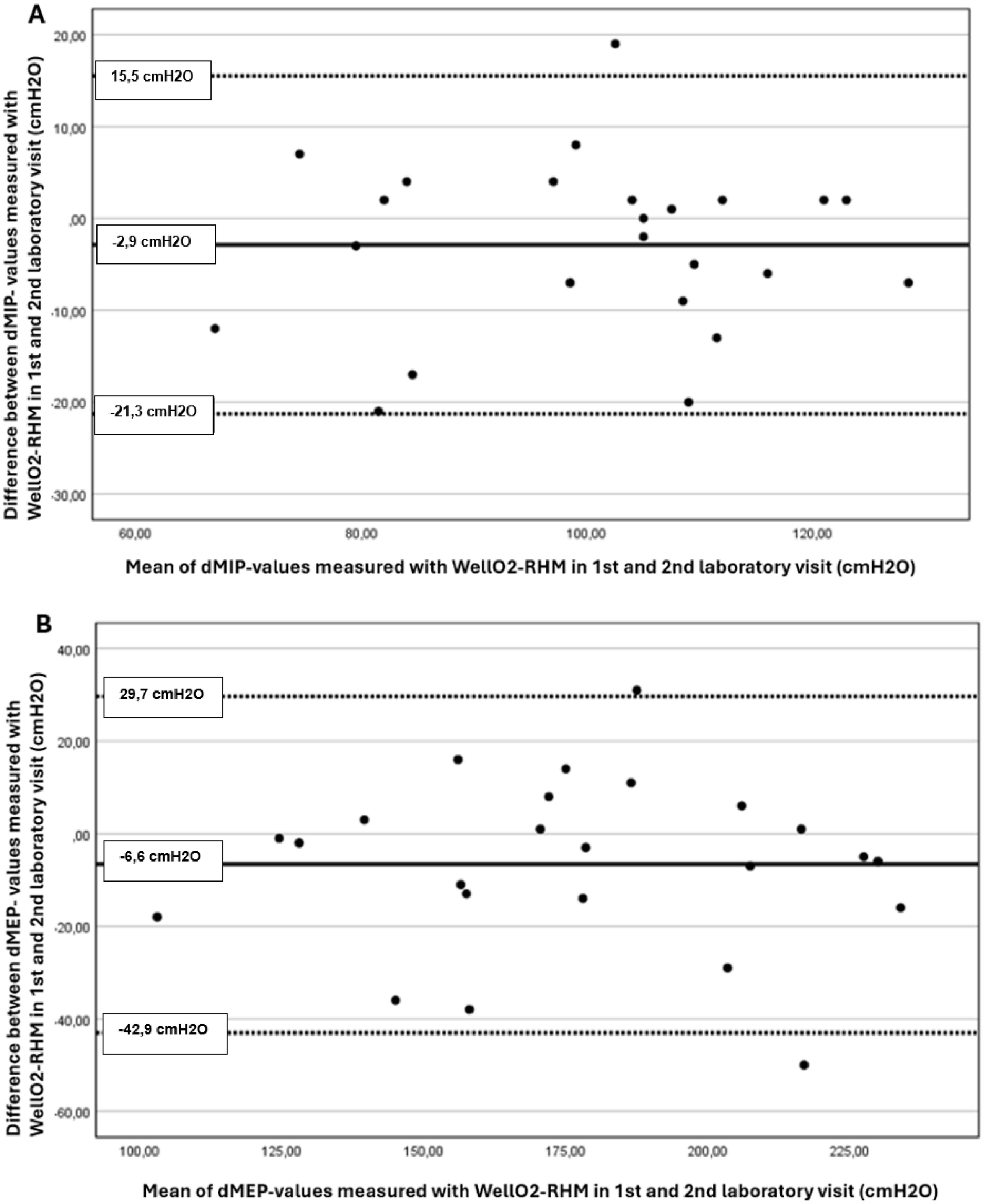

Figure 4 The difference between the first and second measurements of dMIP (**A**) and dMEP (**B**) with the WellO2-RHM, plotted against the mean for each participant. The dotted line shows the 95% limit of agreement.

The participants' MIP and MEP values increased with the number of trials per session when measured using both devices, while the WellO2-RHM values were slightly greater at the second visit than at the first visit, indicating a learning effect. The participants also produced their highest individual dMIP and dMEP values with fewer trials at the second visit, which also suggests a learning effect. This finding agrees with previous findings of a learning effect when measuring MIP on two successive occasions.[27] The presence of a learning effect with novice volunteers implies that the accuracy of the WellO2-RHM could increase with repeated measurements as users become familiar with the procedure.

This study had some significant limitations. First, the number of participants in this study was relatively small, which made it difficult to draw strong conclusions. Moreover, the participants formed a rather homogenous group, representing healthy and physically active young Finnish male and female adults, and hence, it remains to be studied whether the present results would apply to patients e.g. with respiratory or neuromuscular diseases. In addition, the lack of a respiratory muscle-specific warm-up might have increased the learning effect and could have led to a greater variation in intraindividual respiratory pressure values and an increase in the number of trials needed to reach the highest value. Also, the absence of MIP and MEP measurements with the MicroRPM at the first visit could enable some learning effect for the second visit, and this could be a limiting factor for internal validity. Finally, the lack of randomization in the order of performing the MIP and MEP measurements and in the order of device types used might have included systematic bias in the results.

Conclusion

This study revealed that WellO2-RHM is a valid and reliable device for assessment of dMIP and dMEP in healthy and physically active young adults. The results suggest WellO2-RHM can be used in self-monitoring for the effects of respiratory muscle training. Further studies are needed to clarify interrater reliability and the suitability of WellO2-RHM for different subgroups (e.g. those with neuromuscular or lung diseases) or for subjects with older ages.

Abbreviations

ATS, American Thoracic Society; CI, Confidence interval; COPD, Chronic obstructive pulmonary disease; CV, Coefficient of variation; dMEP, Dynamic maximal expiratory pressure; dMIP, Dynamic maximal inspiratory pressure; ERS, European Respiratory Society; FEV1, Forced expiratory volume in one second; FEV1/FVC%, Ratio of forced expiratory volume in one second to forced vital capacity; FVC, Forced vital capacity; IMT, Inspiratory muscle training; ICC, Intraclass correlation coefficient; LOA, Limits of agreement; MDC, Minimal detectable change; MEP, Maximal expiratory pressure; MIP, Maximal inspiratory pressure; PEF, Peak expiratory flow; RMT, Respiratory muscle training; RHM, Respiratory health meter; RPM, Respiratory pressure meter; RV, Residual volume; SEm, Standard error of measurement; SD, Standard deviation; TLC, Total lung capacity; VC, Vital capacity.

Data Sharing Statement

The datasets generated and analyzed during the study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The Human Sciences Ethics Committee of the University of Jyväskylä approved the study design (749/13.00.04.00/2020). All study participants provided written informed consent before inclusion. The study followed the principles outlined in the Declaration of Helsinki.

Consent for Publication

This article and all the materials have a consent for publication.

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Author`s Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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This study has no funding to declare.

Disclosure

The third author (IK) is a minor shareholder of WellO2 Ltd. The first (HR), second (AS) and third (IK) authors are members of the scientific advisory board of WellO2 Ltd. All the other authors declare no conflicts of interest in this work.

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