ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2002 Vol. 45, Št. 1: 31 - 38

# Ventilatory and anthropometric variables in healthy female students from the University of Ljubljana

## Ventilacijski in antropometrični parametri zdravih študentk Univerze v Ljubljani

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**Abstract.** Forced expiratory vital capacity (FEVC) and forced expiratory volume in the first second ($FEV_1$) were measured in healthy, non-smoking female students from the University of Ljubljana. The sample included 86 students, none active in sports, ranging in age from 18-23 years. The results were analysed in terms of anthropometric variables, and regression equations were derived. Comparisons were made with Europaean Respiratory Society (ERS) prediction equations derived from non-Slovenian populations, commonly used in our medical practice. The ERS and our equations predict significantly different values for FEVC and insignificantly for $FEV_1$. According to comparisons of $r^2$ and SD of residuals, we presumed that newly derived equations can be better predictors of ventilatory parameters for Slovene female students population.

**Keywords:** students, female, physiology, ventilation, spirometry, anthropometry, vital capacity, forced expiratory volume.

**Izvleček.** Pri zdravih študentkah nekadilkah, ki se s športom ne ukvarjajo aktivno, smo merili forsirano ekspiratorno vitalno kapaciteto (FEVC) in forsirani ekspiratorni volumen 1 ($FEV_1$). Vzorec je obsegal 86 študentk ljubljanske universe, starih od 18 do 23 let. Iz izmerjenih antropometričnih parametrov smo izpeljali dve regresijski enačbi za izračun FEVC in $FEV_1$ Rezultate smo primerjali z rezultati Evropskega respiratornega združenja (ERS), ki se običajno uporabljajo v medicinski praksi. Izmerjene vrednosti FEVC značilno in vrednosti $FEV_1$ neznačilno presegajo predvidene evropske standarde. Smatramo, da so za slovensko žensko populacijo naše predikcijske enačbe primernejše, zato priporočamo uporabo lastnih standardov.

**Ključne besede:** študentke, fiziologija, spirometrija, antropometrija, vitalna kapaciteta, forsirani ekspiratorni volumen.

## Introduction

Lung volumes and spirometric tests are routinely used to evaluate the normality of respiratory functions. This is achieved by comparing laboratory measured values with those predicted from multiple regression equations that have been developed on a reference sample; the equations frequently use age and body height as independent or predictor variables (WITHERS & al. 1989a, BECKLAKE & al. 1991, QUANJER & al. 1993). There are often very significant variations in predicted values for lung function indices. Such variation reflects, among other considerations (BECKLAKE & al. 1991, ZUSKIN & al. 1996), differences in the population studied, equipment used to measure lung functions and methodology employed. As there are, at present, no references values for any adult Slovenian population, the results of spirometric testing have been mostly evaluated using reference values developed in other populations of Europe. Many studies have found that using reference values developed in other populations of Europe and North America in practice are inadequate for some lung function parameters (WITHERS & al. 1989a,b, SMOLEJ-NARANČIĆ & al. 1991, BRÄNDLI & al. 1996). The objectives of this investigation were, therefore, to define the correlations between spirometric values and measured anthropometric variables and to provide reliable standards in the form of prediction equations.

## Subjects and methods

The study included 86 non-smoking female students, not participating in active sports. Only students without a history of respiratory illness or not showing its symptoms before or during the study and without chest wall deformity were included. We used a Standardized Medical Research Council questionnaire (QUANJER & al. 1993) to screen the subjects on the basis of having:

1. never suffered from asthma, chronic bronchitis, pneumonia, pulmonary tuberculosis, pleurisy
2. never had a persistent cough and/or phlegm for at least 3 months in a year
3. never had chest surgery and/or a major chest injury
4. never lived in a heavily polluted environment

The students came from different parts of Slovenia, but the majority of them were from the city of Ljubljana. On average, they were 20.2 years old. All the measurements were performed in the autumn of 1996 between 8am and 1pm, by the same technician.

## Spirometry

Pulmonary function tests consisted of measuring forced expiratory vital capacity (FEVC) and its subdivision, forced expiratory volume in the first second ($FEV_1$). The results were recorded according to recommendations of the European Respiratory Society (QUANJER & al. 1993). Tests were conducted at an altitude of 350m above mean sea level, using a Spiro 323 spirometer (P.K. Morgan Instruments, Inc.). The spirometer was calibrated on a daily basis, using a precision syringe. Barometric pressure, water vapour pressure and ambient temperature were recorded daily. Recorded volumes were expressed as body temperature and pressure saturated with water vapour (BTPS). All the tests were performed with the subjects in a sitting possition and a nose-clip was used. Prior to their commencement, a careful demonstration of the tests was given to the subjects. FEVC measurements were repeated until three FEVC values were obtained that varied no more than 100 ml or 5%, and the highest values accepted. The data in Tab. 1 demonstrate a high degree of test retest reliability for ventilatory and anthropometric variables. For predicting lung volumes of the non-smoking adult woman, we used the equations recommended by the European Respiratory Society (QUANJER & al. 1993) that are commonly used in Slovenian medical practice (see Tab. 4). They were derived from studies carried out on adult subjects (18-70 years) of European descent, who were non-smokers and without (previous) disease which could compromise their ventilatory function.

Table 1: Test-retest reliability statistic for lung volumes and selected anthropometric variables
Tabela 1: Napaka meritve izmerjenih ventilacijskih parametrov in antropometričnih mer

| Variable | Mean of the first measurements | Mean of the second measurements | $\overline{\lvert d \rvert}$ | SEE | r |
|---|---|---|---|---|---|
| FEVC (l) | 4.14 | 4.11 | 0.11 | 0.09 | 0.97 |
| $FEV_1$ (l) | 3.58 | 3.59 | 0.07 | 0.06 | 0.98 |
| Weight (kg) | 60.6 | 60.8 | 0.21 | 0.37 | 0.99 |
| Height (cm) | 167.1 | 167.2 | 0.12 | 0.51 | 0.98 |
| Sitting height (cm) | 88.1 | 87.8 | 0.29 | 0.45 | 0.97 |
| Arm span (cm) | 165.6 | 165.9 | 0.26 | 0.57 | 0.99 |
| Shoulder width (cm) | 37.2 | 37.2 | 0.03 | 0.38 | 0.93 |
| Width of chest (cm) | 26.1 | 26.1 | 0.02 | 0.45 | 0.94 |
| Depth of chest (cm) | 16.1 | 16.3 | 0.27 | 0.46 | 0.90 |
| Chest circumference at TLC (cm) | 90.1 | 90.5 | 0.38 | 1.09 | 0.93 |
| Chest circumference at FRC (cm) | 84.5 | 84.6 | 0.11 | 1.27 | 0.94 |
| Chest circumference at RV (cm) | 87.0 | 86.6 | 0.42 | 1.20 | 0.94 |
| Thickness of triceps skin-fold (mm) | 14.2 | 13.9 | 0.37 | 0.62 | 0.97 |
| Thickness of subscapular skin-fold (mm) | 11.2 | 10.9 | 0.22 | 0.67 | 0.98 |
| Thickness of midaxillary skin-fold (mm) | 10.1 | 10.4 | 0.33 | 1.14 | 0.96 |
| Thickness of suprailiac skin-fold (mm) | 12.5 | 12.2 | 0.26 | 1.21 | 0.97 |
| Thickness of medial calf skin-fold (mm) | 16.1 | 15.9 | 0.29 | 0.94 | 0.98 |

FRC: functional residual capacity
RV: residual volume
$\overline{\lvert d \rvert}$: mean of the absolute differences
SEE: standard error of estimate
r: the coefficient of reliability

## Anthropometry

Anthropometric variables were measured according to the requirements of the International Biological Programme (WEINER & LOURIE 1969), using standard anthropometric equipment. Stature was measured with an Siber-Hegner anthropometer to an accuracy of 0.1 cm. Body weight was measured on digital Soehnle scales to an accuracy of 0.1 kg. Skin-fold thicknesses were taken with a John Bull calliper, under a constant pressure of 10 $gmm^{-2}$. The same instruments were used throughout the study.

## Statistical analyses

All the statistical analyses were performed using a pocket Statistica 4.3 Statsoft program. After checking variables for normality and linearity of distribution, bivariate correlations between measured parameters were calculated. Forward stepwise multiple regression analyses were made to derive equations for predicting FEVC and $FEV_1$ values from the best weighted combination (with significance $p<0.01$) of anthropometric or other predictor variables. All anthropometric parameters were included in the regression. Equations were validated with a t-test for testing for differences between correlation coefficients (POLLARD 1977). We used two correlation coefficients: $r_1$ (between FEVC or $FEV_1$ values recorded and FEVC or $FEV_1$ values predicted with ERS equations) and $r_2$ (between FEVC or $FEV_1$ values recorded and FEVC or $FEV_1$ values predicted according to our equations). If there were any statistically significant ($p<0.05$) differences between $r_1$ and $r_2$ we presumed that the commonly used and newly derived equations were predicting significantly different values for ventilatory parameters. The choice of the best equation was based on an analyses of residuals, a comparison of the residual standard deviation, i.e. standard error of estimate (SEE) and comparison of the proportion of total variance in lung function explained by the model ($r^2$).

## Results

The mean values and standard deviations for lung volumes, age and selected anthropometric variables are listed in Tab. 2. The mean FEVC was 4.2 liters and $FEV_1$ was 3.7 liters. The correlation matrix of measured variables, shown in Tab. 3, demonstrate that the measurements of the chest correlated significantly with FEVC and $FEV_1$, but weaker than height, sitting height and arm span. The thicknesses of skin-folds were negatively correlated with ventilatory parameters, but only for medial calf skin-fold the correlation was statistically significant.

Table 2: The mean values and standard deviations for measured parameters
Tabela 2: Povprečja in standardne devijacije izmerjenih parametrov

TLC: total lung capacity

| Variable | Mean | SD |
|---|---|---|
| FEVC(l) | 4.2 | 0.46 |
| $FEV_1$(l) | 3.7 | 0.40 |
| Age (years) | 20.2 | 1.50 |
| Weight (kg) | 60.7 | 7.98 |
| Height (cm) | 167.0 | 5.78 |
| Sitting height (cm) | 87.8 | 3.05 |
| Arm span (cm) | 165.2 | 7.00 |
| Shoulder width (cm) | 36.0 | 1.76 |
| Width of chest (cm) | 25.9 | 1.31 |
| Depth of chest (cm) | 15.9 | 1.22 |
| Chest circumference at TLC (cm) | 89.6 | 5.05 |
| Chest circumference at FRC (cm) | 86.3 | 5.28 |
| Chest circumference at RV (cm) | 84.3 | 5.36 |
| Thickness of triceps skin-fold (mm) | 15.7 | 4.31 |
| Thickness of subscapular skin-fold (mm) | 11.2 | 3.44 |
| Thickness of midaxillary skin-fold (mm) | 10.8 | 4.62 |
| Thickness of suprailiac skin-fold (mm) | 13.3 | 5.41 |
| Thickness of medial calf skin-fold (mm) | 17.0 | 6.25 |

FRC: functional residual capacity
RV: residual volume

Table 3: The correlation matrix of measured variables

Tabela 3: Korelacije izmerjenih parametrov

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 FEVC(l) | | 0.76* | 0.20 | 0.27* | 0.64* | 0.51* | 0.61* | 0.50* | 0.31* | 0.37* | 0.41* | 0.35* | 0.30* | -0.15 | -0.11 | -0.15 | -0.04 | -0.27* |
| 2 $FEV_1$(l) | | | 0.13 | 0.17 | 0.62* | 0.49* | 0.60* | 0.31* | 0.22* | 0.29* | 0.29* | 0.25* | 0.24* | -0.20 | -0.15 | -0.16 | -0.11 | -0.30* |
| 3 Age (years) | | | | -0.12 | -0.18 | -0.33 | -0.14 | -0.13 | -0.18 | 0.13 | 0.05 | -0.05 | -0.00 | -0.08 | -0.07 | -0.01 | -0.04 | -0.16 |
| 4 Weight (kg) | | | | | 0.42* | 0.42* | 0.43* | 0.38* | 0.54* | 0.73* | 0.81* | 0.83* | 0.82* | 0.46* | 0.30 | 0.37* | 0.47* | 0.15 |
| 5 Height (cm) | | | | | | 0.90* | 0.90* | 0.60* | 0.67* | 0.12 | 0.56* | 0.53* | 0.43* | -0.11 | -0.30 | -0.19 | -0.17 | -0.41* |
| 6 Sitting height (cm) | | | | | | | 0.76* | 0.48* | 0.72* | 0.14 | 0.52* | 0.56* | 0.47* | 0.00 | -0.12 | -0.12 | -0.16 | -0.16 |
| 7 Arm span (cm) | | | | | | | | 0.63* | 0.68* | 0.14 | 0.57* | 0.49* | 0.39* | -0.09 | -0.34 | -0.14 | -0.15 | -0.39* |
| 8 Shoulder width (cm) | | | | | | | | | 0.44* | 0.13 | 0.45* | 0.38* | 0.30 | -0.12 | -0.21 | -0.14 | -0.01 | -0.33 |
| 9 Width of chest (cm) | | | | | | | | | | 0.34 | 0.67* | 0.68* | 0.63* | 0.05 | -0.14 | -0.04 | -0.10 | -0.15 |
| 10 Depth of chest (cm) | | | | | | | | | | | 0.65* | 0.69* | 0.68* | 0.28 | 0.18 | 0.34 | 0.27 | 0.10 |
| 11 Chest circumference at TLC (cm) | | | | | | | | | | | | 0.95* | 0.93* | 0.10 | 0.05 | 0.21 | 0.12 | -0.14 |
| 12 Chest circumference at FRC (cm) | | | | | | | | | | | | | 0.98* | 0.17 | 0.18 | 0.24 | 0.14 | -0.06 |
| 13 Chest circumference at RV (cm) | | | | | | | | | | | | | | 0.22 | 0.27 | 0.30 | 0.18 | 0.02 |
| 14 Thickness of triceps skin-fold (mm) | | | | | | | | | | | | | | | 0.64* | 0.55* | 0.51* | 0.68* |
| 15 Thickness of subscapular skin-fold (mm) | | | | | | | | | | | | | | | | 0.71* | 0.59* | 0.50* |
| 16 Thickness of midaxillary skin-fold (mm) | | | | | | | | | | | | | | | | | 0.62* | 0.32 |
| 17 Thickness of suprailiac skin-fold (mm) | | | | | | | | | | | | | | | | | | 0.30 |
| 18 Thickness of medial calf skin-fold (mm) | | | | | | | | | | | | | | | | | | |

$p<0.05$
TLC: total lung capacity
FRC: functional residual capacity

RV: residual volume

The regressions of lung functions parameters on anthropometric variables contributing significantly to the description of lung volumes and the ERS equations, are given in Tab. 4. The evaluated prediction equation for FEVC included the chest circumference at total lung capacity, the thickness of midaxillary skin-fold, of medial calf skin-fold and of triceps skin-fold. The prediction equation for $FEV_1$ is based on the chest circumference at residual volume, the thickness of midaxillary skinfold and on shoulder width. As shown, the observed values exceeded those predicted by ERS equations by, on average, 0.20 liters for FEVC and 0.22 liters for $FEV_1$.

Table 4: Regression equations for FEVC and $FEV_1$, evaluated on a sample of female students, and ERS equations, the percent of explained variance and the standard error of estimation for FEVC in FEV1
Tabela 4: Regresijski enačbi za izračun FEVC in $FEV_1$ izpeljani iz populacije študentk in ERS enačbi, prikaz deleža pojasnjene variabilnosti v vzorcu in standardne napake pri oceni dejanske FEVC in FEV1

| Lung volume | Evaluated regression equations | $r^2$ % | Diff. | SD | SEE |
|---|---|---|---|---|---|
| FEVC(l) | 0.054CCT – 0.042TMS – 0.029TCS + 0.020TTS | 47.6 | 0.00 | 0.336 | 0.237 |
| $FEV_1$(l) | 0.040CCR – 0.045TMS + 0.024SW | 24.5 | 0.00 | 0.348 | 0.246 |
| | ERS equations (QUANJER & al. 1993) | | | | |
| FEVC(l) | 4.43H – 0.026A – 2.89 | 33.5 | 0.20 | 0.367 | 0.259 |
| $FEV_1$(l) | 3.95H – 0.025A –2.60 | 34.6 | 0.22 | 0.322 | 0.228 |

CCT: chest circumference at total lung capacity (cm)
TMS: thickness of midaxillary skin-fold (mm)
TCS: thickness of medial calf skin-fold (mm)
TTS: thickness of triceps skin-fold (mm)
CCR: chest circumference at residual volume (cm)
SW: shoulder width (cm)
H: body height (cm)
A: age (years)
$r^2$:% of explained variance
Diff: difference between mean observed and mean predicted
SD: standard deviation of residuals
SEE: standard error of estimate FEVC and $FEV_1$

The correlation coefficients, listed in Tab. 5, show that ERS equations and our regression equations predict statistically significant different values for FEVC and insignificantly for $FEV_1$.

Table 5: Testing for difference between observed and predicted FEVC and $FEV_1$
Tabela 5: Razlika med dejanskimi in predvidenimi vrednostmi FEVC in $FEV_1$

| | FEVC(l) | t | $FEV_1$(l) | t |
|---|---|---|---|---|
| $r_1$ | 0.58 | 2.49* | 0.59 | 0.90 |
| $r_2$ | 0.68 | | 0.49 | |

$p<0.05$

$r_1$ = correlation coefficient between observed and by ERS equations predicted volumes

$r_2$ = correlation coefficient between observed volumes and volumes predicting according to our equations

## Discussion and conclusions

The results shown are valid for a healthy, non-smoking population of female students from the University in Ljubljana. Prediction equations for FEVC and $FEV_1$ frequently use age and body height (WITHERS & al. 1989a, BECKLAKE & al. 1991, QUANJER & al. 1993) as predictor variables. However, due to the narrow age range in this group (18-23 years), the correlation of lung functions with age is low and statistically insignificant (Tab. 3). A sample population with a greater age range would show a significant, negative correlation between age and the measured ventilatory parameters, as it is known (KNUDSON & al. 1977) that in an ageing adult population, the values of lung functions fall, principally due to a loss in elasticity of the lung and thoracic walls.

The uniformity of body height and age, is the cause of them not demonstrating good prediction of lung functions. Correlations between lung functions and the body length measurements such as body and sitting height, were higher and statistically significant. It is know that FEVC and $FEV_1$ values highly depends on stature (COTES & al. 1979, MALIK & al. 1972).

Thorax dimensions show also positive and significant correlations with FEVC and $FEV_1$. SING & BHASIN (1983) allege that such correlations are more evident in people who live at high altitude. The quantity of fatty tissue under the skin correlates negatively with ventilatory parameters (COLLINS & al. 1995, LAZARUS & al. 1997) as shown in Tab. 3. The correlation between body weight and lung functions is characteristically positive for which the cause is most likely the muscle-bone body component (BRODAR 1981) that in early adulthood, show a higher positive correlation with body weight. In ageing populations of constant body weight, the proportion between body fat and lean body weight changes in favour of the fat component. Negative correlations between increased body weight at the expense of acquired fat and lung functions are seen (CHEN & al. 1993, CHINN & al. 1996, WANG & al. 1996).

ERS prediction equations commonly used in Slovenia, on average underestimate actual ventilatory values, FEVC and $FEV_1$ as shown in Tab. 4. The independent variables which contributed significantly to the description of a dependent variable FEVC in the derived regression equation are chest circumference at total lung capacity (TLC), thickness of midaxillary, medial calf and triceps skin-folds. No improvement of $r^2$ or SEE was obtained in regression analyses by the addition of other variables.

Using a t-test, we determined that the commonly used and our regression equation predict significant different values of FEVC, that in practice would mean a significantly different interpretation of ventilatory functions (Tab. 5). We believe, that the newly formed regression equation is a better predictor of FEVC in the female student population in Slovenia.

$FEV_1$ in the derived regression equation can be predicted from the chest circumference at residual volume (RV), shoulder width and thickness of triceps skin-fold. From Tab. 5, it is evident that the predictor of $FEV_1$ is not significantly different with the commonly used and newly derived regression equation. We believe that our equation can be a predictor of $FEV_1$ in a population of female students, but are unable to say that it is better than the ERS equation.

We conclude with an observation that measurements of FEVC and $FEV_1$ on average, significantly exceed the values of those predicted with the ERS equations. This is the result of the difference between the Slovenian population and the population from which are derived the ERS equations that we use in practice. To provide reliable standards, we must derive regression equations on a larger and more heterogeneous sample.

## Povzetek


Ventilacijske funkcije vrednotimo s spirometričnimi metodami, tako, da izmerjene vrednosti ventilacijskih parametrov primerjamo z referenčnimi. Referenčne vrednosti navadno izračunamo z regresijskimi enačbami, ki so spolno specifične in kot neodvisne spremenljivke vključujejo starost in telesno višino. V Sloveniji nimamo svojih standardov, zato ventilacijske funkcije vrednotimo z regresijskimi enačbami izpeljanimi na drugih evropskih populacijah.

Namen tega dela je bil izpeljati regresijske enačbe za izračun forsirane ekspiratorne vitalne kapacitete (FEVC) in forsiranega ekspiratornega volumna 1 ($FEV_1$) iz antropometričnih mer zdravih slovenskih študentk, ki se s športom aktivno ne ukvarjajo.

Antropometrične meritve smo izvajali po mednarodnih priporočilih - IPB (WEINER & LOURIE 1969), spirometrijo pa v skladu z zahtevami Evropskega respiratornega združenja – ERS (Quanjer & al. 1993).

Povprečna FEVC slovenskih študentk znaša 4,3 litra, povprečni $FEV_1$ pa 3,7 litra (Tab.2). Mere prsnega koša so značilno pozitivno povezane z vrednostima ventilacijskih funkcij, vendar šibkeje kot dolžinske mere telesa. Debelina kožnih gub značilno negativno korelira z FEVC in $FEV_1$ (Tab.3). Izmerjena ventilacijska parametra v povprečju presegata vrednosti izračunane z ERS predikcijskima enačbama, in sicer za 0.20 litra v primeru FEVC in 0.22 litra za $FEV_1$. Izpeljali smo regresijsko enačbo za izračun FEVC iz mere obsega prsnega koša ob največjem vdihu ter debeline kožne gube na tricepsu, goleni in midaksilarne kožne gube. Regresijska enačba za izračun $FEV_1$ vključuje obseg prsnega koša ob izdihu do rezidualnega volumna, širino ramen in debelino midaksilarne kožne gube (Tab.4). ERS regresijska enačba predvideva značilno drugačne vrednosti FEVC kot naša regresijska enačba, kar pa ne velja za $FEV_1$ (Tab.5). ERS regresijske enačbe podcenjujejo dejanske vrednosti FEVC in $FEV_1$ slovenskih študentk. Navedeno lahko privede do napačnega vrednotenja pljučnih funkcij v tej skupini. Menimo, da izpeljana regresijska enačba za izračun FEVC predvideva vrednosti, ki so bližje dejanskim kot ERS enačba. Regresijska enačba za $FEV_1$ pa vrednosti, ki so najmanj toliko podobne dejanskim kot izračuni z ERS enačbo.

Zaključujemo, da potrebujemo lastne standarde, s katerimi bi lahko pravilno vrednotili ventilacijske funkcije slovenskih študentk.


## Acknowledgements


The authors wish to thank all the subject participants in the study. The authors are also grateful to doc.dr. Mirjam Lasan and prof.dr. Janko Sušnik for their valuable comments and suggestions.

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