

Antropometrični merilni stol (AMC) - naprava za ugotavljanje veličin prsnega koša, potrebnih za oceno delovanja pljuč pri ljudeh

Measuring Device AMC (Anthropometric Measuring Chair) for Lung Function Prediction in Normal, Disproportional and Paralyzed People

Zvone Balantič · Peter Novak · Jurij Šorli

Namen te študije je zasnova merilne naprave za ugotavljanje antropometričnih veličin prsnega koša ter razvoj računalniškega programa za določanje referenčnih vrednosti delovanja pljuč na podlagi teh meritev.

Konstrukcija merilne naprave upošteva vse zakonitosti ergonomiske lege merjenca, tako da enakovredno vključuje tudi paralizirane osebe. Konstrukcija merilne naprave zagotavlja enake pogoje merjenja in dovolj veliko natančnost pri meritvi različnih oseb. V študijo merilne naprave je bilo po naključnem vzorcu vključenih 34 zdravih oseb iz alpskega področja Slovenije. Merjene osebe žive v normalnem okolju, so povprečno telesno aktivne. Vsi so bili nekadičci. Pljučna funkcija je merjena s spirometrijo in plethysmografijo. Računalniški program CSR temelji na matematičnem modelu s 24 vhodnimi spremenljivkami in 9 izhodnimi parametri pljučne funkcije.

Sedna višina (SV), višina (V), razpon rok (RR) in druge antropometrične veličine prsnega koša lahko bistveno določijo delovanje pljuč glede na starost (S) in spol. Dobljeni rezultati so primerljivi z referenčnimi vrednostmi, izračunanimi po standardih CECA [1] in [2]. Natančnost ocene pljučne funkcije je večja z uporabo večjega števila vhodnih veličin in z uporabo zahtevnejšega matematičnega modela.

Z uporabo merilne naprave AMC smo zagotovili boljši približek izmerjene vrednosti delovanja pljuč kakor z običajno uporabljenimi metodami za določanje referenčnih vrednosti. Merilna naprava z merilnim postopkom in s spremljajočo računalniško podporo bi bila lahko uporabna tudi za določanje delovanja pljuč invalidnih oseb, pri katerih ni mogoče natančno merjenje višine telesa.

© 1999 Strojniški vestnik. Vse pravice pridržane.

(Ključne besede: naprave merilne, veličine antropometrične, testi pljučne funkcije, odvisnosti)

The aim of this study was to build a measuring device for assessment of anthropometric values of the thorax and development of a computer program for lung function prediction, based on these measurements.

The design of the measuring device takes into consideration all the ergonomic particularities of a human subject, as well as paralyzed humans. This design assures equal measuring condition and sufficiently great measuring precision on diverse persons. The study was carried out on 34 healthy non-smokers. All persons reside in the Alpine region of Slovenia. They live in normal circumstances and have been fairly physically active. The lung function was measured by traditional spirometry and plethysmography. The computer program CSR (computer simulation of respiration) was based on a mathematical model with 24 measured input variables and 9 lung function output parameters.

The sitting height (SH), height (H), arm span (AS) and other measurements of the thorax were used to predict lung function according to age (A) and sex. The results were comparable to the values obtained according to CECA standards [1] and [2]. The reliability (as measured by decreased SD) increases with the number of predictor variables included in the regression equations.

Anthropometric measurements of the thorax (with AMC) may have the potential to more accurately predict lung function than the standard equations across ethnic groups. This measuring device procedure and computer program could also be used for lung function prediction in patients when the usual anthropometric data (such as height) cannot be measured with acceptable precision (paralyzed subjects).

© 1999 Journal of Mechanical Engineering. All rights reserved.

(Keywords: measuring device, anthropometric values, lung function tests, regression)

0 UVOD

Proučevanje rezultatov večletnih meritev delovanja pljuč je pokazalo, da se vrednosti rezultatov teh testov prevečkrat pojavljajo zunaj dovoljenih priporočil - zunaj 1,64 standardnega odstopanja. Priporočila CECA (Commission des communautés européennes)

0 INTRODUCTION

The study of the test results over several years led us to the conclusion that the results of lung function tests were beyond the recommended limits - 1.64 standard deviation - far too often. CECA European standards (Commission des communautés européennes) [1]

europeennes) [1] in [2] temeljijo na spolu, starosti in višini človeka. Po oceni medicinskih strokovnjakov so tudi zdravi ljudje odstopali iz omenjenega območja, kar je pomenilo uvrščanje teh oseb v področje patoloških sprememb. Znano je tudi, da obstaja pomembna razlika v vrednostih delovanja pljuč med posameznimi etničnimi skupinami [3] in [4]. Tudi na alpskem področju Slovenije so opazovanja pokazala, da je število preiskovancev z vrednostmi testov nad zgornjo mejo predvidene norme večje kakor bi pričakovali. Narodne značilnosti, ki jih opredeljuje CECA z uvedbo korekcijskih faktorjev, smo mi skušali objektivno nadomestiti z nekaterimi antropometričnimi vrednostmi prsnega koša in z drugimi izbranimi veličinami. Poiskali smo veličine, ki naj bi značilno vplivale na oceno delovanja pljuč.

Namen je bil torej ugotoviti in izmeriti ustrezne antropometrične veličine ter napraviti primeren matematični model z računalniškim simuliranjem. Pri konstruiranju merilne naprave smo izhajali iz geometrijske oblike sodčasto-stožčastega prostora, ki ga obsegajo pljuča. Izbor vključenih antropometričnih veličin je temeljil na verodostojnosti popisa geometrijske oblike pljuč z razvojem metodologije določanja delovanja pljuč.

1 METODOLOGIJA

Hrbtenica v prsnem predelu, rebra in prsnica sestavljajo ogrodje toraksa in vsi trije elementi ograjajojo sodčasto-stožčasti prostor, ki se med dihanjem razteza in krči. Pri dihanju se zgornji del torakalnega prostora giblje predvsem v anterioposterialni smeri, spodnji del torakalnega prostora pa v lateralni, kar se pri obeh spolih kaže različno. Različna gibanja reber povzročajo tudi različne smeri rotacije hrbtničnih vretenec [5]. Najpomembnejša respiratorna mišica je prepona, ki pri mirovanju opravlja večji delež dela izmenjave plinov. Ker med dihanjem obstaja stalno ravnotežje med raztegovanjem pljuč in toraksom, je iz izbranih zunanjih mer mogoče sklepati o torakalnem in pljučnem prostoru za posamezno osebo. Znano je, da se med vdihom rebra usmerijo naprej in tako glede na izdih zanahajo za približno 20 odstotkov v anterioposterialni smeri [6]. Normalno in mirno dihanje se opravlja skoraj izključno le s prepono, zato je bilo za določitev naših izhodišč treba vključiti predvsem opazovanja stacionarnih točk ob največjem vdihi in največjem izdihu, kjer sodeluje tudi preostalo mišičevje.

Zgradili smo merilno napravo AMC (antropometrični merilni stol) (sl. 1), s katero smo sledili končnim točkam vdiha in izdiha ter jih zapisali. Sedna površina stola je od tal oddaljena 440 mm, kar omogoča udobno vzravnano sedenje [7]. Osnovna sedna konstrukcija je izdelana iz jeklenih cevi, ki omogočajo ustrezno togost. Na zadnjo stran merilne naprave so pristavljeni preostali merilni pripomočki, ki pa so izdelani iz aluminijskih profилov. Sedna površina je opremljena z omejilnim naslonom. Na zadnji strani je nameščena glavna navpična merilna letev, po kateri drsi merilo za merjenje sedne višine, naslon za glavo, merilo za merjenje razpona rok in nosilni okvir za merila

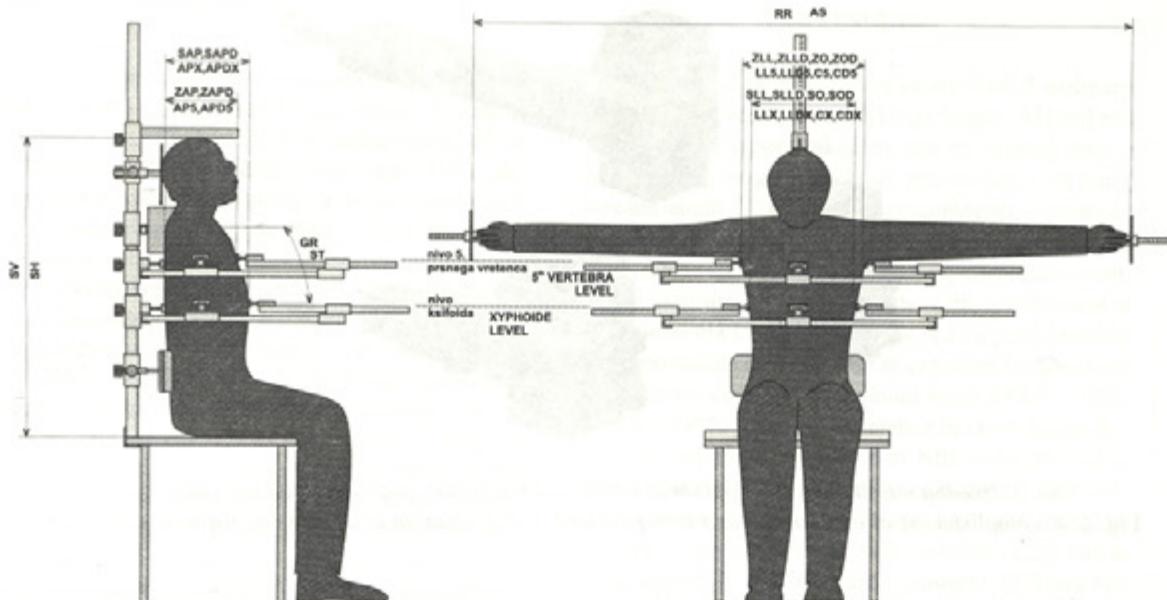
and [2] define the standard result values in tabular form for men and women of different age and height. In our opinion even healthy persons showed deviations outside the standard value of 1.64, which placed them in the range of pathologic changes. Significant differences exist between predicted values among different ethnic groups [3] and [4]. Research in Alpine region of Slovenia has shown a larger number of lung volume measurements above the expected values. Possible methods for overcoming these ethnic differences would include determination of suitable ethnic correction factors or investigation of additional anthropometric measurements which might help define the lung function parameters with a greater degree of precision.

Our aim was to find those anthropometric values which influence the lung function most and to make a suitable mathematical model by computer simulation. The chosen values would substitute for values used so far. Design of the device followed the barrel shaped cylinder in which the lungs are located. The choice of anthropometric values was based on development of lung geometry with lung function prediction methodology.

1 METHODS

The thoracic part of the spine, the ribs and the sternum create the barrel shaped cylinder of the thorax, which expands and contracts during respiration. During respiration the upper part of the thorax moves mainly in an anterioposterior direction and the lower part in a lateral direction, which is manifested differently in men and women. The various rib movements also cause different vertebral rotations [5]. The main respiratory muscle is the diaphragm which is mainly responsible for the gas exchange when body is at rest. As there is always a stable equilibrium between lung expansion and the thorax during respiration, it is possible to define the capacity of the lungs cavity for each individual by means of external measurements. We know that during inspirium the ribs push forwards and, according to the expirium, shift by 20% in an anterioposterior direction [6]. As relaxed respiration is performed mainly by the diaphragm, the maximum strain on the inspiratory and expiratory muscles has also to be included.

We constructed a measuring device called AMC (anthropometric measuring chair) (Fig. 1), which made it possible to record the extreme points of inspirium and expirium. The seat of the chair is 440 mm high, which allows for comfortable sitting [7]. The steel structure of the chair provides rigidity of the frame on which the other measuring devices are mounted. On the back side, the main vertical measuring rail along which the measure for sitting height can slide, there are placed the head rest, the arm stretch measure and the frame for measuring the anterioposterior (AP) and laterolateral (LL) dimensions of thorax. The measur-



Sl. 1. Merjenec na AMC-u s ponazoritvijo merilnih mest

Fig. 1. The position of the person on AMC - chair with schematic presentation of measurements

anterioposterialne (AP) in laterolateralne (LL) dimenzijs prsnega koša. Merilne letve z merilno skalo so vzdolžno nastavljive, z njihovo pomočjo pa izmerimo absolutne vrednosti merjenih antropometričnih veličin. Na teh merilnih letvah je pritrjen tudi merilnik za opravljanje relativnih meritev oz. določanje največjih odmikov pri vdihu in izdihu.

Pri konstruiranju nosilnega in merilnega aluminijškega okvira z vsemi pripadajočimi drsnimi elementi smo se izognili varjenju in nastajajočim topotnim deformacijam, zato smo za spajanje uporabili večnamensko konstrukcijsko lepilo Kemiskol L 725. Strižna trdnost lepnega spoja je dosegla 35 MPa, kar pomeni polovično vrednost trdnosti osnovnega materiala. Lepni spoj smo oblikovali tako, da smo čim bolje poskrbeli za strižne površine (sl. 2).

2 PREIZKUS

Merjena oseba je z ledvenim delom prislonjena na naslon sedne površine, s hrbitičnim vretencem na umerjevalno točko AP merilne letve in z glavo na naslon za glavo. Dve točki je mogoče uravnnavati in prirediti ukrivljenosti hrbitnice ter tako ustvariti popolne razmere za vzravnano držo telesa. Vodoravna drsna letev za merjenje razpona rok je navpično nastavljiva, zato jo namestimo v višini vodoravne odročitve rok. Merjenec razširi roke v odročno lego, iztegne dlani ter jih obrne naprej. Z omejilnimi ploščami se dotaknemo iztegnjenih sredincev na obeh rokah in razberemo razpon rok. V tej legi telesa izmerimo tudi sedno višino na glavni navpični merilni letvi. Navpično nastavljiv okvir z merili za meritve AP in LL prsnega koša namestimo v višini petega prsnega vretanca in na nivoju ksifoida (koniec grodnice). Na obeh mestih odberemo absolutne dimenzijs AP in LL prsnega koša ter relativne nihanja ob vdihu in izdihu. Nazadnje z mehkim tračnim merilom pomerimo še dolžino prsnice ter absolutne dimenzijs obsegov prsnega koša na prvem in drugem nivoju ob vdihu ter izdihu.

ing rails with measuring scale are longitudinally adjustable. In this way absolute measures of anthropometric values are measured. For the definition of maximum deviation by inspirium and expirium a relative measuring gauge fixed on measuring rails is used.

The design of the steel support and aluminium measuring frame with all sliding elements is not welded because of heat deformations. Instead, we used structural glue Kemiskol L 725. The tangential tension of the glue connection reached 35 MPa, which is half of the value of the basic material tension. The glue connection is designed so that a tangential surface presence is provided (Fig. 2).

2 EXPERIMENT

The person's lumbar part is placed against the back of the chair with the vertebrae on the measuring point AP and the head on its head-rest. Two measuring points can be adjusted to the subject's spine curve so that ideal conditions for upright posture of the body can be created. The horizontal sliding rail is vertically adjustable, and it should be set in the position of horizontal arm stretch. The person stretches his arms and hands with the palms turned in a forward direction. The arm stretch is measured by measuring plates at the tips of both middle fingers. In this position, the sitting height is also measured on the vertical measuring rail. The vertical adjustable frame with rail is placed at the fifth vertebra and at the xyphoid level. The absolute AP and LL dimension are read at both places. The absolute dimensions and relative oscillations are taken during maximum inspirium and maximum expirium. After that the absolute measures of thorax are taken at both levels with a tape measure during inspirium and expirium, and the sternum is measured.

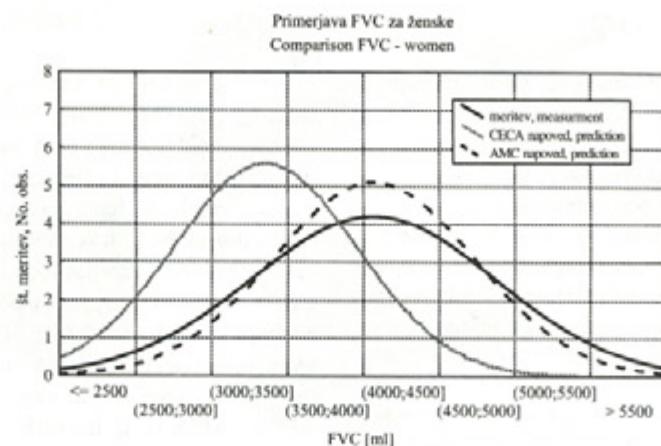


Diagram 1. Primerjava normalnih porazdelitev FVC pri ženskah
Diagram 1. Comparison of normal distributed FVC - women

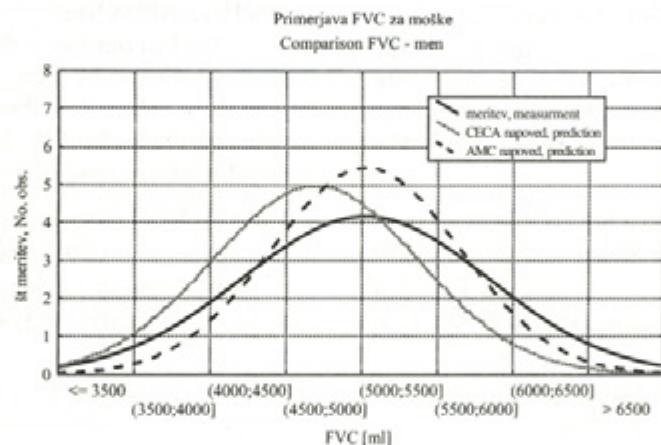


Diagram 2. Primerjava normalnih porazdelitev FVC pri moških
Diagram 2. Comparison of normal distributed FVC - men

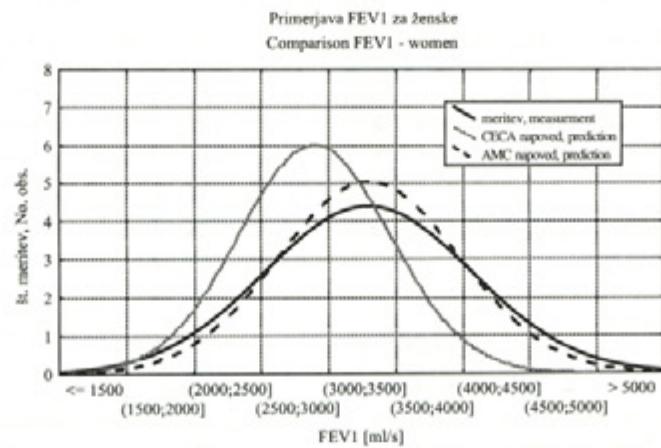
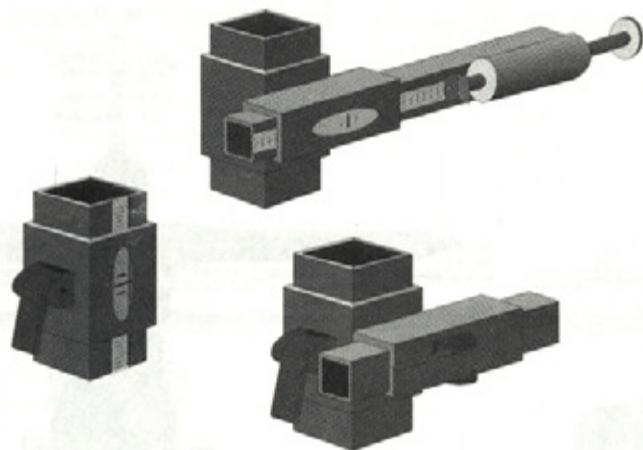


Diagram 3. Primerjava normalnih porazdelitev FEV₁ pri ženskah
Diagram 3. Comparison of normal distributed FEV₁ - women



Sl. 2. Izvedba merilne glave s tipalom in konstrukcijska rešitev pozicioniranja merilnih letev
Fig. 2. Accomplishment of measuring head with palp and design solution of positioning the measuring rails

V nadaljevanju smo z uporabo spirometrije in pletizmografije opravili še meritve delovanja pljuč [8] do [10], kjer smo izmerili (sl. 3):

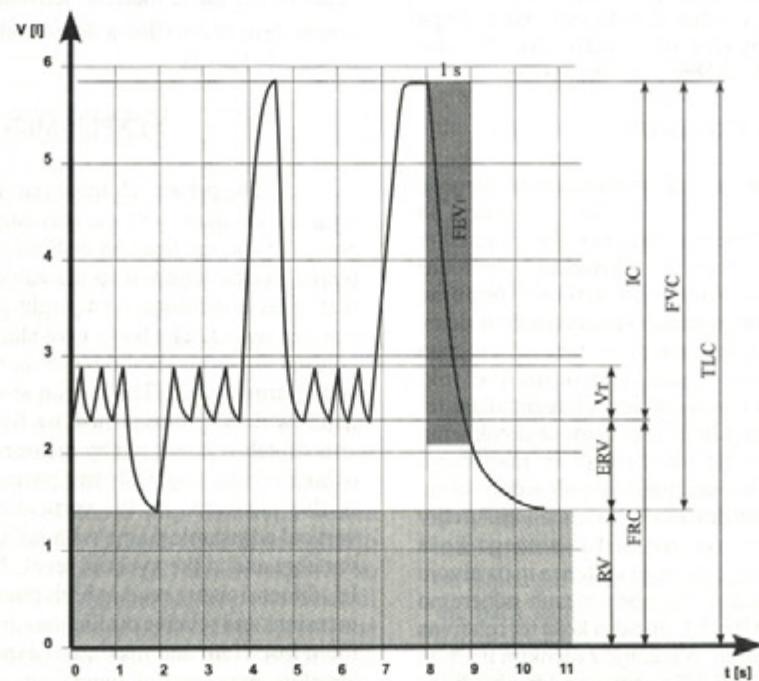
- forisirano vitalno kapaciteto - FVC v ml,
- forisirano ekspiratorno prostornino v prvi sekundi - FEV₁ v ml/s,
- forisirani ekspiratorni tok od 25% do 75% največje vrednosti FVC - FEF₂₅₋₇₅ v ml/s,
- Tiffeneaujev indeks - razmerje med FEV₁ in FVC v %,
- ekspirirano rezervno prostornino - ERV v ml,
- rezidualno prostornino - RV v ml,
- funkcionalno rezidualno kapaciteto - FRC v ml,
- upornost v dihalnih poteh - R_{aw} v kPa·s/l in
- celotno pljučno kapaciteto - TLC v ml.

Metoda merjenja delovanja pljuč je običajna in povzeta po mednarodnih normativih [11] do [14].

In addition the lung function tests were carried out [8] to [10], during which we defined (Fig. 3):

- forced vital capacity - FVC in ml,
- forced expiratory volume per 1 second - FEV₁ in ml/s,
- forced exp. flow - meaning flow during exhalation from 25 to 75% of the FVC - FEF₂₅₋₇₅ in ml/s,
- Tiffeneau index - ratio between FEV₁ and FVC in %,
- expiratory reserve volume - ERV in ml,
- residual volume - RV in ml,
- functional residual capacity FRC in ml,
- flow resistance in the airways - R_{aw} in kPa·s/l,
- total lung capacity - TLC in ml.

The method of testing the lung function is classical and follows the international standards [11] to [14].



Sl. 3. Prostornine in kapacitete pljuč
Fig. 3. Lung volumes and capacities

3 REZULTATI

V statistični obdelavi smo torej zajeli 3 običajne podatke: starost - S leta, maso - M v kg, višino - V v cm in 17 vrednosti, izmerjenih na AMC-u: sedna višina - SV v cm, razpon rok - RR v cm, dolžino sternuma - GR v cm, obseg prsnega koša v nivoju petega prsnega vretenca in v višini ksifoida pri vdihu / izdihu ZOE / ZOI, SOE / SOI v cm, laterolateralna globina v višini petega prsnega vretenca in v višini ksifoida pri vdihu / izdihu ZLLE / ZLLI, SLLE / SLII v cm, anteroposterialna dimenzija v višini petega prsnega vretenca in v višini ksifoida pri vdihu / izdihu ZAPE / ZAPI, SAPE / SAPI v cm, razlika obsega prsnega koša pri izdihu in vdihu v višini petega prsnega vretenca in v višini ksifoida ZOD, SOD v cm. Določili smo tudi štiri posredno izmerjene vrednosti: razlika laterolateralne globine pri izdihu in vdihu v višini petega prsnega vretenca ZLLD in v višini ksifoida SLLD v cm, razlika anteroposterialne dimenzije pri vdihu in izdihu v višini petega prsnega vretenca ZAPD v cm, in v višini ksifoida SAPD v cm.

Prva enačba v seriji določanja parametrov pljučne funkcije z uporabo nestandardnih antropometričnih veličin popisuje FVC ženskega dela vzorca, kjer se je izkazalo, da k verodostojnjemu rezultatu prispevajo SV, S, GR in SODIF (standardni odmik: s = 494 ml):

$$\text{FVC} = 30,3 \times \text{SV} - 30,2 \times \text{S} + 117,9 \times \text{GR} + 76,7 \times \text{SODIF} \quad (1).$$

FVC moškega dela vzorca pa najbolje popisujejo naslednji parametri; RR, SOI, SLLE in ZAPDIF (s = 550 ml):

$$\text{FVC} = 33,5 \times \text{RR} - 86,5 \times \text{SOI} + 222,7 \times \text{SLLE} + 211,0 \times \text{ZAPDIF} \quad (2).$$

Naslednja dvojica enačb popisuje odvisnost FEV₁ pri ženskah (s = 363 ml/s):

$$\text{FEV}_1 = -10,3 \times \text{SV} - 134,6 \times \text{ZLLI} + 46,2 \times \text{RR} + 151,6 \times \text{ZODIF} \quad (3),$$

in moških (s = 387 ml/s):

$$\text{FEV}_1 = 81,2 \times \text{SV} - 92,4 \times \text{SOI} + 130,2 \times \text{SLLE} + 109,3 \times \text{GR} - 185,8 \times \text{SODIF} + 86,0 \times \text{ZODIF} \quad (4).$$

V diagramih 1 do 4 je prikazana primerjava normalnih porazdelitev eksperimentalnih rezultatov delovanja pljuč z napovedmi CECA in z rezultati napovedi AMC-a.

Normalna porazdelitev vsebuje vrednosti, ki so zbrane v preglednicah 1 in 2.

4 RAZPRAVA

Spirometrija je zelo razširjena metoda ocenjevanja bolezenskih sprememb in je tudi primerna za epidemiološke študije. V Evropi so bili leta 1971 izoblikovani in sprejeti standardi CECA, ki so bili zapisani v preglednični obliki [1]. Ocenjevanje subjektov po teh standardih se je izkazalo za zelo

3 RESULTS

The data processing comprised 3 ordinary data: age - A [years], mass - M [kg], height - H [cm] and 17 additional values taken on our measuring device AMC: sitting height - SH [cm], arm stretch - AS [cm], sternum length - ST [cm], chest circumference in expirium / inspirium at the fifth vertebra and at xyphoid level CES / C15, CEX / CIX [cm], absolute laterolateral chest diameter in expirium / inspirium at the fifth vertebra and at xyphoid level LLE5 / LL15, LLEX / LLIX [cm], absolute anteroposterior chest diameter in expirium / inspirium at the fifth vertebra and at xyphoid level APE5 / API5, APEX / APIX [cm], the difference in chest circumference by expirium/ inspirium at fifth vertebra and at xyphoid level CD5, CDX [cm]. Four indirectly taken values were also defined: laterolateral depth difference by expirium / inspirium at the fifth vertebra LLD5 and at xyphoid level LLBX [cm], anteroposterior difference by expirium / inspirium at the fifth vertebra APD5 and at xyphoid level APDX [cm].

The first equation in the series of defining lung function parameters by means of unconventional anthropometric values describes the FVC of a female sample and shows that SH, A, ST and CDX are necessary for reliable results (RSD = 494 ml):

$$\text{FVC} = 30,3 \times \text{SH} - 30,2 \times \text{A} + 117,9 \times \text{ST} + 76,7 \times \text{CDX} \quad (1).$$

FVC of male sample is best described by AS, CIX, LLEX and APD5 (RSD = 550 mL):

$$\text{FVC} = 33,5 \times \text{AS} - 86,5 \times \text{CIX} + 222,7 \times \text{LLEX} + 211,0 \times \text{APD5} \quad (2).$$

The next pair of equations describes the FEV₁ relation in women (RSD = 363 ml/s)

$$\text{FEV}_1 = -10,3 \times \text{SH} - 134,6 \times \text{LL15} + 46,2 \times \text{AS} + 151,6 \times \text{CD5} \quad (3),$$

and men (RSD = 387 ml/s):

$$\text{FEV}_1 = 81,2 \times \text{SH} - 92,4 \times \text{CIX} + 130,2 \times \text{LLEX} + 109,3 \times \text{ST} - 185,8 \times \text{CDX} + 86,0 \times \text{CD5} \quad (4).$$

Diagrams 1 to 4 show a comparison of normal distributed experimental lung function results with CECA predictions and with AMC predictions.

The normal distribution contains the values presented in Table 1 and Table 2.

4 DISCUSSION

Spirometry is the best and simplest test of lung function, used also in anepidemiological setting. The CECA normal values from 1971(1) matched the values measured in our population quite well, but the concept of normal value range - defined at 20 % deviation from the mean value as normal - was questioned. The

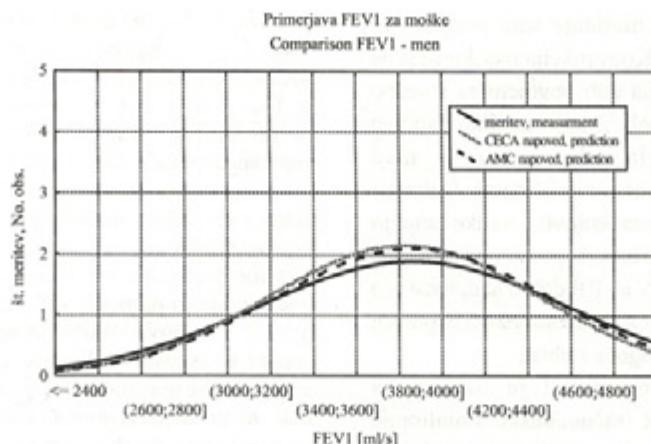


Diagram 4. Primerjava normalnih porazdelitev FEV_1 pri moških
Diagram 4. Comparison of normal distributed FEV_1 - men

Pregl. 1. Povprečne vrednosti (\bar{x}) in standardni odstopki (s) za FVC in FEV_1 pri merjencih, ki so bili vključeni v študijo
Table 1. Average values \bar{x} and SD for FVC and FEV_1 by study included subjects

parameter pljučne funkcije: lung function parameter:	moški men		ženske women	
	\bar{x}	SD	\bar{x}	SD
izmerjeni FVC measured FVC ml	5023	814	4067	807
FVC (CECA) ml	4693	682	3353	607
FVC (AMC) ml	5026	623	4068	664
izmerjeni FEV_1 measured FEV_1 ml/s	3866	720	3293	771
FEV_1 (CECA) ml/s	3822	632	2893	564
FEV_1 (AMC) ml/s	3865	647	3298	674

Preglednica 2. Primerjava med merjeno vrednostjo FVC in FEV_1 ter napovedjo CECA in napovedjo AMC-a
(r - koeficient korelacije, p - stopnja pomembnosti)

Table 2. Measured FVC and FEV_1 comparison between CECA and AMC prediction
(r - correlation coefficient, p - significance)

relacija: relation:	moški men		ženske women	
	r	p	r	p
izmerjeni FVC - FVC (CECA) measured FVC - FVC (CECA)	0,66	0,00394	0,73	0,00069
izmerjeni FVC - FVC (AMC) measured FVC - FVC (AMC)	0,79	0,00014	0,83	0,00003
izmerjeni FEV_1 - FEV_1 (CECA) measured FEV_1 - FEV_1 (CECA)	0,72	0,00105	0,80	0,00011
izmerjeni FEV_1 - FEV_1 (AMC) measured FEV_1 - FEV_1 (AMC)	0,89	0,00001	0,90	0,00001

zamudno in nezanesljivo merjenje smo potrebovali ustreznou merilno napravo. Konstrukcija merilnega stola z imenom AMC je zadostila tudi pogoju za izvedbo meritev pri invalidnih osebah. Z našo merilno napravo so bile določene korelacijske povezave med uporabljenimi antropometričnimi veličinami. Dokazali smo odvisnost nekaterih spremenljivk z veliko stopnjo soodvisnosti in primerno stopnjo pomembnosti ($p < 0,05$), tako npr. z merjenji SV ali RR dobro nadomestimo telesno višino osebe. Tudi ZOE je uporaben pri napovedi telesne teže, ko osebe ni mogoče stehtati.

Naš matematični model je osnova za računalniški program CSR (računalniško simuliranje respiracije) [15] in [16]. Za moške in ženske se pojavljajo različni antropometrični indeksi, kar kaže na to, da sta oblika in gibljivost prsnega koša med spoloma različni, saj k izmerjeni pljučni prostornini in pretokom ne prispevata v enaki meri. Merilna naprava AMC ni bila uporabljena samo za dokaz povezanosti posameznih antropometričnih veličin, pač pa je bila namenjena predvsem za hitro, preprosto, dovolj natančno in zanesljivo merjenje antropometričnih veličin prsnega koša pri sedečem človeku. Ocena pljučne funkcije, ki izhaja iz meritev na merilni napravi AMC je bila primerjana z ocenami drugih avtorjev, predvsem pa s standardi CECA [1] in [2]. V naši študiji nismo namerno iskali nesorzazmerno grajenih oseb, saj bi bilo pri teh osebah še pomembnejše upoštevati dodatne antropometrične meritve za napoved vrednosti parametrov delovanja pljuč.

Odprto ostaja vprašanje ocene delovanja pljuč z našo napravo za specifične skupine ljudi (športniki, potapljači, rudarji, kadilci itn.). Posebna prednost uporabe naše merilne naprave se kaže pri invalidih, ki do sedaj niso imeli primerne metode za določanje delovanja pljuč.

Merilna naprava AMC je bila zasnovana za specifične potrebe naše študije in je v taki obliki manj primerna za splošno uporabo v dihalnih laboratorijih. Razbiranje antropometričnih mer je potekalo ročno z zadovoljivo natančnostjo ± 1 mm, vendar je bilo v pogledu ambulantne uporabe prepočasno. Primerna je namestitev infrardečih zaznaval na vseh merilnih mestih, ki so potrebni za primerno določitev delovanja pljuč. Povezava merilne naprave z računalnikom bi omogočila neposredni pretok signalov in njihovo obdelavo v že pripravljenem računalniškem programu CSR. S tako povezano bi lahko popolnoma avtomatizirali delo v dihalnih laboratorijih in v zelo kratkem času z veliko zanesljivostjo ocenili delovanje pljuč merjene osebe.

Naš matematični model je zasnovan na vzorcu slovenskih prebivalcev, ki se verjetno razlikujejo od evropskega povprečja. Razlika je torej v lastnostih, ki jih v ocenah normalnih vrednosti samo na podlagi telesne višine in starosti ne zajamemo.

problem is that the degree of deviation from the mean value does not depend on the absolute value of the spirometric parameter in adults, but is rather independent of it. Therefore CECA 1983 normal values were designed in the form of linear prediction equations. Computerized data input and calculation favored predictions based on a regression equation, and the various input variables were easily modified and studied. CECA 1983 normal values use only the sex, height and age of a subject for prediction of spirometric parameters, disregarding anthropometric differences in the habitus of a person. The problem also arises in cases when height cannot be measured directly. In our study we tried to answer these questions. The results of our study showed that many unconventional anthropometric parameters (derived from the thorax measurements) are needed to predict the level of normal lung function in adults. We bonded Lung function parameters to sitting height, arm span and other thorax anthropometric values. For suitable and rapid measurements, we needed some measuring device. The design of a measuring device, named AMC, was satisfactory for lung function prediction of paralyzed subjects. It was applied in order to define the correlation coefficient for the anthropometric values used. We proved the dependence of some variables with a great degree of correlation coefficient and suitable significance ($p < 0.05$). Subject height was suitably substituted by SH and AS. If it is not possible to weigh the person, then CES is a suitable prediction.

Our computer program named CSR (computer simulation of respiration) [15] and [16] is based on our mathematical model. The anthropometric values are different for men and women. The thorax shape and movement are different in both sexes. The two parameters did not contribute equally to lung function. The AMC measuring device was used not only to give proof of the anthropometric values connection but also for quick, simple, exact and reliable measurement of the thorax anthropometric values on a sitting subject. Lung function prediction, measured on AMC, was compared with lung function prediction by other authors, first of all with CECA norms [1] and [2]. We did not try to find disproportional subjects, but it did prove necessary for the most important additional anthropometric measuring to be considered.

The question about special group subjects lung function prediction remains open (sportsmen, divers, miners, smokers, etc.). These measures were also used to predict the height of a paraplegic patient by measuring the sitting height (SH) or armspan (AS).

The measuring device AMC was used to project for our specific studies. It was less suitable for respiratory laboratory ordinary usage. Anthropometric value measuring was manually read with ± 1 mm accuracy. The measuring procedure is too slow for general usage. For lung function prediction it is logical to place infrared sensors on the AMC. It is possible to establish an AMC connection to the computer and perform simultaneous computer scanning/analysis on lung function prediction and laboratory work.

Our mathematical model uses a Slovenian population sample. Our population is probably different to the European average. This difference is included in the anthropometric properties (H and A).

5 SKLEP

Merilna naprava AMC je izpolnila zastavljene naloge in je omogočila pridobivanje načrtovanih antropometričnih veličin prsnega koša. Merilna naprava z matematičnim modelom in računalniškim programom uspešno zaokrožuje prispevek k bazični sprememb postopka določanja delovanja pljuč pri človeku in omogoča enakopravno obravnavo normalnih, nesorazmernih in paraliziranih oseb [17].

5 CONCLUSION

The AMC measuring device measured up to expectations, and it planned for thoracic anthropometric values to be made. The AMC measuring device, mathematical model and computer program completed the measuring protocol successfully. The advantage of using anthropometric values in lung function prediction - beside body height, age and sex - is of greatest value in handicapped persons and in all persons with a disproportional habitus who deviate from the "population's mean value", the one that best suits the current predicted values [17].

6 LITERATURA
6 REFERENCES

- [1] CECA - Commission des communautés européennes . Collection d'hygiène et de médecine du travail N°.11. Aide - memoire pour la pratique de l'examen de la fonction ventilatoire par la spirographie., 2^e édition revue et complétée, Luxembourg 1971.
- [2] Quanjer, P.H., Andersen, L.H., Tammeling, G.J.: Static lung volumes and capacities. Report of Working Party for Standardisation of Lung Function Tests. Journal of the Societas Europaea Physiologiae Clinicae Respiratoriae. Bulletin Européen de Physiopathologie Respiratoire. Supplement 5 , Volume 19, 1983, 11-21.
- [3] Malik, M.A., Moss, E., Lee, W.R.: Prediction values for the ventilatory capacity in male West Pakistani workers in the United Kingdom. Thorax, 27, 1972, 611-619.
- [4] Yang, T.-S., Peat, J., Keena, V., Donnelly, P., Unger, W., Woolcock, A.: A review of the racial differences in the lung function of normal Caucasian, Chinese and Indian subjects. Eur Respir J, 4, 1991, 872-880.
- [5] Wolf, D., Keidel, Heinz Bartels: Kurzgefasstes Lehrbuch der Physiologie. 5.überarbeitete und erweiterte Auflage; Stuttgart: Thieme, 1979; 4.1-4.41.
- [6] Arthur, C. Guyton: Textbook of medical physiology. Fifth edition - illustrated W.B.Saunders Company Philadelphia, London; Toronto. 39, 1976.
- [7] Stephen, Pheasant, Bodyspace: Anthropometry, ergonomics and design; Philadelphia: Taylor & Francis, 1986; p. 111.
- [8] ATS Statement. Standardisation of spirometry: 1987 update, Am Rev Respir Dis 1987, 136(5), 1285-1298, Concurrent publication in Respir Care, 1987, 32(11), 1039-1060.
- [9] American Association for Respiratory Care. Clinical practice guideline: spirometry, Respir Care, 1991, 36(12), 1414-1417.
- [10] Quanjer, P.H., Tammeling, G.J., Cotes J.E., Pedersen, O.F., Peslin, R., Yernault, J-C.: Lung volumes and forced ventilatory flows, Report working party standardization of lung function tests European community for steel and coal, Official statement of the European respiratory society. Eur Respir J, 1993, 6, Suppl. 16, 5-40.
- [11] Mayer, M., Navratil, M., Křišťufek, P.: Guidelines for standardised evaluation of pulmonary function testing in Czechoslovakia; European Journal of Respiratory Diseases 62; Suppl 113; 1981: 77-78.
- [12] Mead, J.: Une introduction au langage de la mécanique ventilatoire. Bull Physiopathological Respiration 7; 1971: 5-15.
- [13] Bedell, G.N., Marshall, R., DuBois, A.B., Comroe, J.H.: Plethysmographic determination of the volume of gas trapped in the lungs; J Clin Invest 1956; 35: 664-670.
- [14] Gardner, R.M., Clausen, J.L., Crapo, R.O., Epler, G.R., Hankinson, J.L., Johnson, J.L. Jr, Plummer, A.L.: American thoracic society committee on proficiency standards for clinical pulmonary laboratories. Quality assurance in pulmonary function laboratories. Am Rev Respir Dis 134(3): 1986; 625-627.
- [15] Balantič, Z., Novak, P., Šorli, J., Kandare, F.: Computer simulation and didactic visualisation of lung volume changes, 6th International Conference on Home Mechanical Ventilation. Lyon: 1997: A120.
- [16] Balantič Z., Fležar M., Novak P., Šorli J., Kandare F.: Computer simulation of lung volumes and ventilatory capacities using anthropometric data obtained on the anthropometric measuring chair (AMC): Respiratory Care, Nov 97, Vol.42, No. 11: 1074
- [17] Balantič, Z.: Dinamični model pljuč z upoštevanjem mehanike dihanja in delovanja pljučne ventilacije. Doktorska disertacija, Univerza v Ljubljani, Fakulteta za strojništvo, 1997

Naslovi avtorjev: dr. Zvone Balantič, dipl. inž.
Zg. Duplje 39a
4203 Duplje

Authors' Addresses: Dr. Zvone Balantič, Dipl. Ing.
Zg. Duplje 39a
4203 Duplje, Slovenia

prof. dr. Peter Novak, dipl. inž.
Fakulteta za strojništvo
Univerze v Ljubljani
Aškerčeva 6
1000 Ljubljana

Prof. Dr. Peter Novak, Dipl. Ing.
Faculty of Mechanical Engineering
University of Ljubljana
Aškerčeva 6
1000 Ljubljana, Slovenia

prof. dr. Jurij Šorli, dr. med.
Bolnišnica Golnik - Klinični oddelki
za pljučne bolezni in alergijo
4204 Golnik

Prof. Dr. Jurij Šorli, MD
University Clinic of Respiratory
and Allergic Diseases Golnik
4204 Golnik, Slovenia

Prejeto: 23.10.1997
Received:

Sprejeto: 27.1.1999
Accepted: