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# Pulmonary Function in Prepubescent Boys: The Influence of Passive Smoking and Sports Training

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ABSTRACT In this paper, we studied prepubescent boys (N = 75; 11.3 years ± 2 months) divided into three groups: two experimental groups and age-paired, non-systematically physically engaged controls (N = 25). The experimental groups consisted of 27 basketball players, and of 23 dinghy sailors. The pulmonary function was established measuring the large airway variables (inspiratory-vital-capacity, forced-vital-capacity, one-second-forced-expiratory-volume) and small airway variables (peak-expiratory-flow, and maximal-expiratory-flow after 50% and 75% exhalation). All variables were measured in absolute values and then presented and compared in relative values - predicted for age and stature. Using the simple originally constructed questionnaire, passive smoking status was observed, and the subjects were additionally sub-sampled as passive smokers, or non-exposed to passive smoking. The multivariate- analysis-of-the-variance (MANOVA) showed significant dominance ($p < 0.05$) of the experimental groups in the large airways variables and small airways variables, for the NS exclusively. No significant MANOVA differences were found between the basketball players and sailors, and between the non-exposed to passive smoking and passive smoking in any of the studied groups. The results of the present study indicate a positive influence of the systematic physical exercising on the pulmonary function, with no differential effects of the two-year basketball and dinghy sailing sports training on the pulmonary function.

KEY WORDS Respiratory Status, Children, Kinesiology, Factor Analysis, Test Construction, Croatia.

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**PULMONARY STATUS IN YOUNG ATHLETES AND NONATHLETES**
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## Introduction

It is accepted and well documented that respiratory volumes, flows, and capacities (pulmonary function (PF)) of growing children and adolescents change mostly as a function of age and consequently as a function of body height (BH). It is defined by an increase in the lung volume, which naturally follows an increase of body proportions, mostly defined by an increase of the BH. However, PF is also dependent on differences in the functionality of the respiratory system, not necessarily related to growth (Peric, Cavar, Zenic, Sekulic, & Sajber, 2014). One of such factors is smoking status. Passive smoking (PS) negatively influences RS (Haby, Peat, & Woolcock, 1994; Nuhoglu et al., 2003; Sherrill et al., 1992), especially to those children whose mothers smoked during pregnancy (Rizzi et al., 2004), and who were exposed to passive smoking during the first five years of life (Wang et al., 1994). Moreover, it is supposed, although not extensively studied, that physical exercise and sport activity positively influence PF in youngsters (Courteix, Obert, Lecoq, Guenon, & Koch, 1997; Goic-Barisic et al., 2006; Nourry et al., 2004). Some authors (Courteix et al., 1997; Nourry et al., 2004) showed a significant improvement in PF of active young athletes in longitudinal studies, and others (Goic-Barisic et al., 2006) identified significant differences in PF between exercised and non-exercised children. However, there are evident disagreements about the possible factors which lead to the dominance of exercised children in the PF variables, in comparison to the non-exercised controls. More precisely, there is no firm evidence that physical training improves PF in humans. However, most of these studies might suffer from sport-selection effects and, therefore, the statistical suppressor effect. Finally, studies investigating the influence of passive smoking and sports training on the PF in children are scarce. Therefore, in this article, we analysed the PF status of prepubescent athletes (basketball players and dinghy sailors) and non-athletes, and studied the possible influence of passive smoking status on their PF.

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We were of the opinion that dinghy sailing (one person sailing in small boats; e.g. Optimist and Cadet sailing class), and basketball are interesting for the purpose of studying PF because of the following: (a) sailing is performed in the open air and sea, which can lead to certain advantages regarding respiratory function (clean and fresh air, aerosols, etc.), but also risks (cold and wind exposure for example); (b) sailing is mostly static and characterized by static muscle contractions, while basketball is a dynamic sport. The difference in dynamics leads to obvious differences in oxygen uptake for those two sports; less than 40 and more than 50 ml/kg/min for sailing and basketball, respectively (Apostolidis, Nassis, Bolatoglou, & Geladas, 2006; Sekulic, Medved, Rausavljevi, & Medved, 2006). Therefore, we presumed the possible differential effects in the PF of the two sports studied.

## Methods

The sample consisted of 75 subjects in total (age 11.3±2 months), divided into two experimental groups (E) and one control group (C; N = 25). The first E group consisted of young dinghy sailors (ES; N = 23), and the second one of young basketball players (EB; N = 27). The C group consisted of boys who were not engaged in any organized sports activity apart from PE. None of the examinees reported any recent health problems and any respiratory diseases. For all the subjects at least one parent was informed about the purpose of the study, giving their informed consent.

PF testing was performed using the Jaeger MasterLab (Erich Jaeger GmbH & CoKG, Wűrzburg, Germany) (Sekulic & Tocilj, 2006; Goic-Barisic et al., 2006; Peric at al., 2014). The same person performed all the tests on the subjects. All the subjects were given standardized instructions on the forced maximal expiratory manoeuvres with a demonstration of the procedures. The tests were performed with the subjects sitting, breathing through a mouthpiece with a nose clip. The spirometer was calibrated by means of two syringes using the instrument's automatic calibration programme. Parameters derived from the flow-volume curves were: inspiratory vital capacity (VCIN) forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), maximal expiratory flow at 50% and 75% exhalation (MEF50 and MEF25). Since the previous studies dealt with two sets of pulmonary variables (Sekulic & Tocilj, 2006), the VCIN, FVC, FEV1 are used to describe the airway obstruction in the large airways (large airways variables (LAV)), whereas PEF, MMEF, and MEF values were used to describe the airway obstruction in the small airways (small airways variables (SAV)).

Apart from PF, body height (BH) and body weight (BW), and skinfold variables were measured which allowed us to calculate body fat percent (BF%) according to the Siri equation (Elberg et al., 2004).

None of the examinees was an active smoker. The passive smoking status was identified using a simple questionnaire consisting of two questions: 1) Is anyone in your household a smoker? (If no) 2) Has anyone of your household quit smoking? When the first question was answered positively, we considered the subject to be a passive smoker (PS). If both questions were answered negatively, we considered the subject to be not exposed to passive smoking (NS). Finally, if only the second question were answered positively, we excluded the subject from the study. The passive smoking status was also verified by one parent. If the parent's result on the questionnaire was in disagreement with the subject's result on the questionnaire, the subject was not included in the study. Accordingly, based on both criteria, the drop-out in the E groups was about 7% (4 subjects). The questionnaire was found to be highly reliable per Spearman's correlation coefficient (0.92) calculated for the test-retest on the questionnaire.

For all the variables, we calculated the descriptive statistics. The student's T-test for the independent (non-correlated samples) was applied to determine the significance of the differences between the groups in anthropometric variables (BH, BW, and BF%). Additionally, the multivariate analysis of the variance (MANOVA) was applied for the purpose of the multivariate comparison of SAV and LAV separately between the different groups of subjects. We calculated MANOVA differences for LAV and SAV within EB, ES, and C regarding the smoking status, and between EB, ES, and C (separately for PS and NS). Factor analysis was used to determine the factor structure and character of the relationships between variables. All the coefficients were considered significant at a level of 0.95 ($p<0.05$). All the calculations were performed using Statsoft's Statistica, version 6.0.

## Results

The EB are the tallest of all subjects and, when compared to ES, dominant in BW. The EB and ES do not significantly differ in BF%, while the highest values of the BW and BF% are found in C group (all presented in Table 1).

TABLE 1 Descriptive statistics (Mean±SD) and t- test significance

| | Total | Sailing (ES) | Basketball (EB) | Control (C) |
|---|---|---|---|---|
| BH (cm) | 155.41 ± 8.13 | 152.09 ± 8.12 | 159.52 ± 9.99 [a] | 154.54 ± 6.32 |
| BW (kg) | 47.04 ± 10.09 | 40.36 ± 6.41 | 45.29 ± 8.12 [a] | 53.55 ± 12.11 [a,b] |
| BF% (%) | 19.61 ± 8.22 | 14.78 ± 3.21 | 16.33 ± 5.21 | 25.89 ± 8.61 [a,b] |

Legend: BH - body height; BW - body weight; BF% - percent of the body fat; [a] significantly different from ES; [b] significantly different from EB



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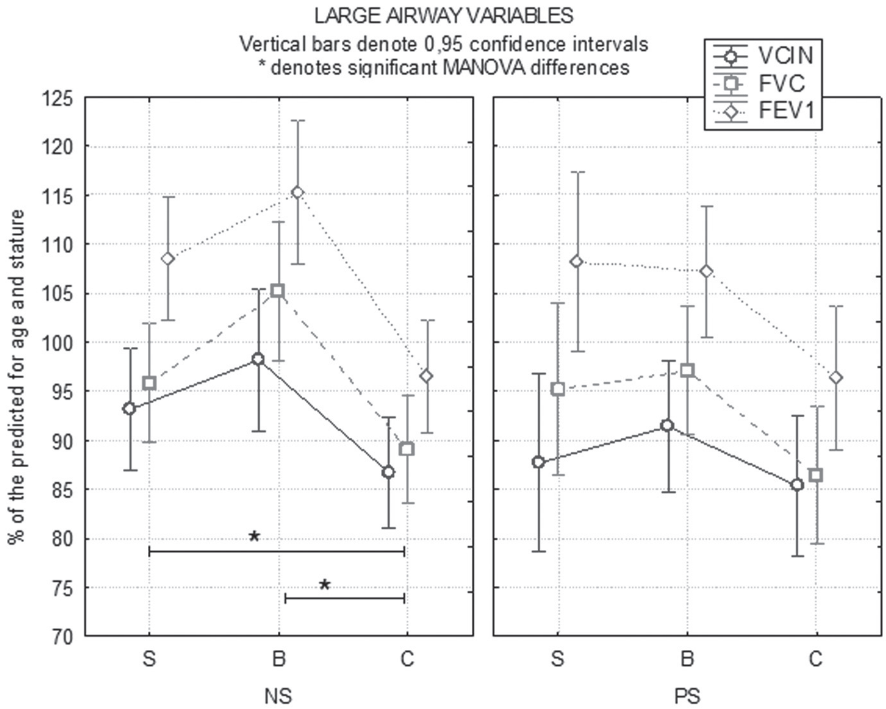


FIGURE 1 Relative values of the large airway variables (mean ± SEM) and multivariate analysis of the variance significance when comparing young sailors (S), young basketball players (B), and control (C), separately in the non-exposed to passive smoking (NS) and passive smokers (PS). VCIN - inspiratory vital capacity, FVC - forced vital capacity, FEV1 - forced expiratory volume in one second, PEF - peak expiratory flow, MEF50 - maximal expiratory flow after 50% exhalation, MEF25 - maximal expiratory flow after 75% exhalation

In Figures 1 and 2, relative LAV and SAV parameters are presented and statistically compared between the groups, separately for PS and NS. Within the NS sub-sample, EB and ES significantly dominate in the relative LAV and SAV values, in comparison to C. In the PS sub-sample, the groups do not differ significantly in LAV, or in SAV.

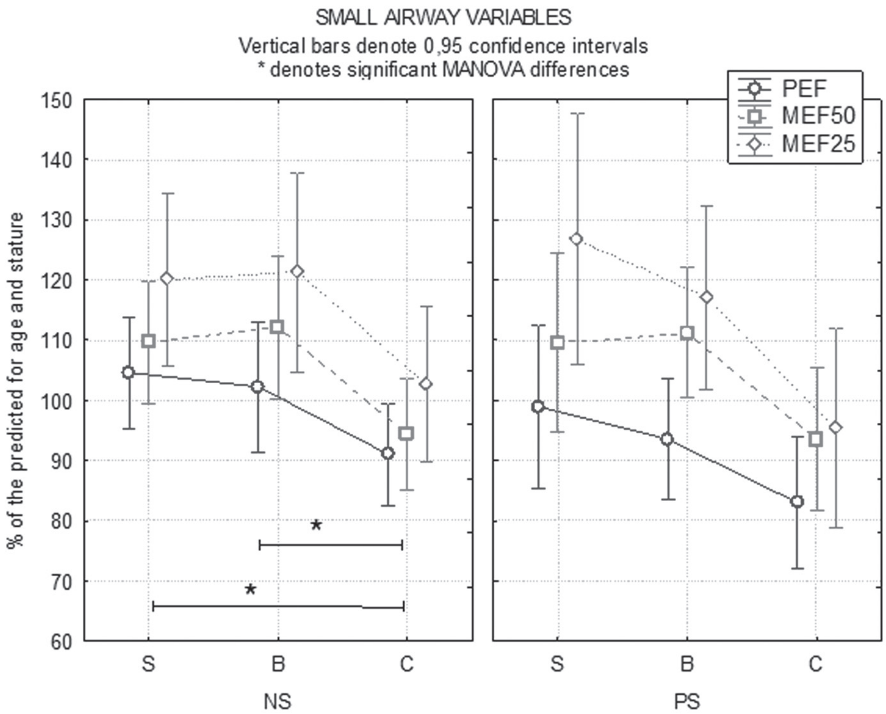


FIGURE 2 Relative values of the small airway variables (mean ± SEM) and multivariate analysis of the variance significance when comparing young sailors (S), young basketball players (B), and control (C), separately in the non-exposed to passive smoking (NS) and passive smokers (PS). VCIN - inspiratory vital capacity, FVC - forced vital capacity, FEV1 - forced expiratory volume in one second, PEF - peak expiratory flow, MEF50 - maximal expiratory flow after 50% exhalation, MEF25 - maximal expiratory flow after 75% exhalation

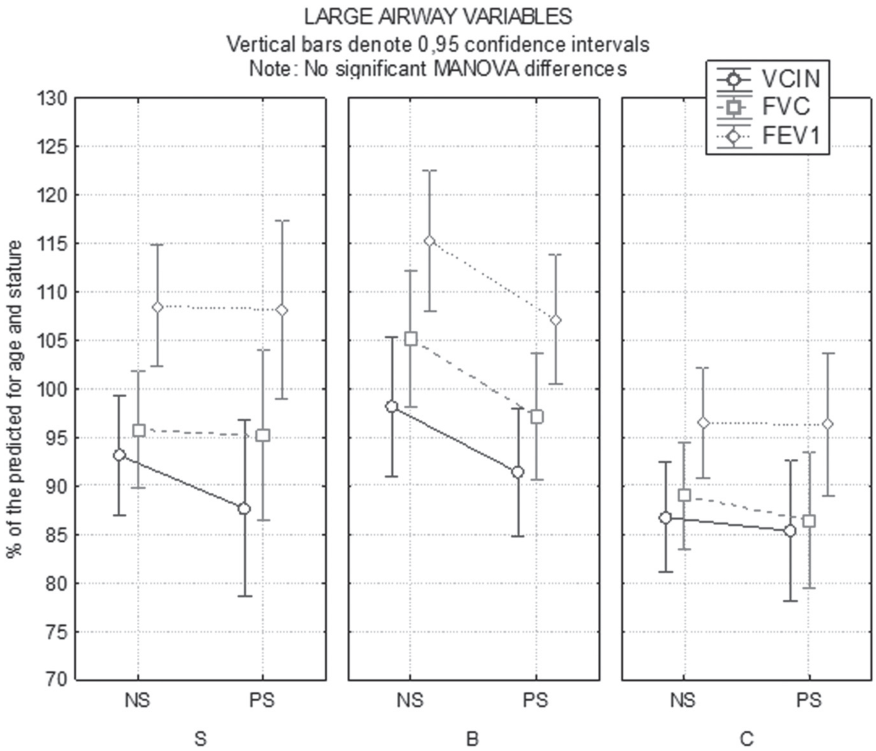


FIGURE 3 Relative values of the large airway variables (mean ± SEM) and multivariate analysis of the variance significance when comparing NS (non-exposed to passive smoking) and PS (passive smokers) in the young sailors (S), young basketball players (B), and control (C). VCIN - inspiratory vital capacity, FVC - forced vital capacity, FEV1 - forced expiratory volume in one second

When comparing PS and NS within the different groups of subjects, we found no significant differences between PS and NS in LAV (Figure 3), or in SAV (Figure 4).

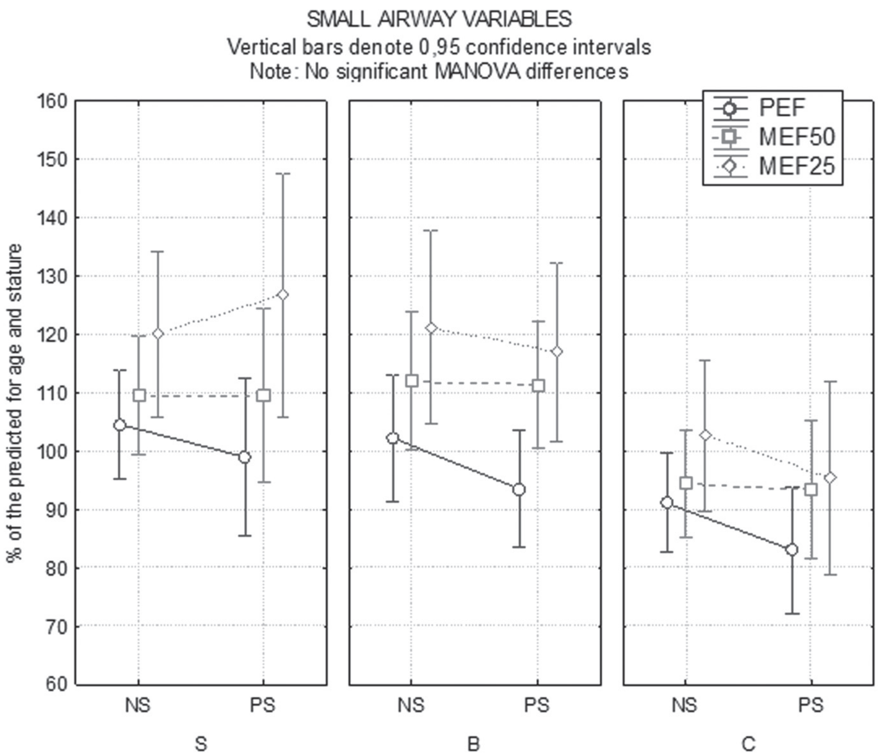


FIGURE 4 Relative values of the small airway variables (mean ± SEM) and multivariate analysis of the variance significance when comparing NS (non-exposed to passive smoking) and PS (passive smokers) in the in the young sailors (S), young basketball players (B), and control (C). PEF - peak expiratory flow, MEF50 - maximal expiratory flow after 50% exhalation, MEF25 - maximal expiratory flow after 75% exhalation

## Discussion

The EB dominance in BH was expected since boys who chose to participate in basketball sports training were significantly taller than others even two years before our experiment (see Table 1). Differences in BF% in which E groups were significantly lower in values than C were also expected. Briefly, the previous studies regularly found that additional physical activity (e.g. sports activity) in pre-pubertal boys leads to more systematic changes in the anthropometric status, when compared to less physically active peers, mostly observable in skinfold and BF measures (Dowda, Ainsworth, Addy, Saunders, & Riner, 2001; Mukhopadhyay, Bhadra, & Bose, 2005; Sekulic, Krstulovic, Katic, & Ostojic, 2006). We found that the groups did not differ significantly in BW, nor triceps skinfold (e.g. body fat). The only difference was found in BH, where EB where significantly taller than ES (see previous text).

Observations and discussion regarding PF are divided into the next paragraphs.

### *Pulmonary function in prepubescent athletes and non-athletes*

The problem of a possible positive influence of physical activity on PF persists. In some prior studies (Zinman & Gaultier, 1987) authors concluded that lung volumes in young athletes (swimmers) could not be accounted for by an increased ability to inflate and deflate the lungs by the respiratory muscles. However, in a more recent study (Courteix et al., 1997), the authors were of the opinion that physical training directly stimulates lung growth by harmonizing the development of the airways and alveolar lung spaces. Since we found the significant dominance of the ES and EB in LAV and SAV variables when comparing them to the less physically active controls, the data presented herein support the idea of a positive influence of physical exercise on the PF in children. However, there are no significant differences between the ES and EB in any of the analysed set of variables. We are of the opinion that two possible explanations have to be indicated for such a condition. First, there is a possibility that two years of active sport participation at such an age (from 9 to 11 years of age) is a relatively short period for any significant differential effects of the two different sports (in our case, sailing and basketball) on the PF in young athletes. It is especially apparent if we observe the numerical (although not significant) dominance of the EB in comparison to ES in most of the LAV (Figure 3). Hence, it is possible that the dynamic character of the basketball game, and the higher oxygen consumption, assure a more generative basis for the PF development, mostly by encouraging larger respiratory excursions. There are some opinions that it can result in a larger ventilatory or total lung capacities without necessarily reflecting more or larger alveoli (Merkus, Ten Have-Opbroek, & Quanjer, 1996). It seems logical that such changes are more observable in LAV than in SAV, where no observable numerical differences can be found between ES and EB (Figure 3). Another option for the nonsignificant differences in PF between ES and EB can be found in the system of the calculation of the relative PF values. Briefly, young basketball players are in the tallest two percentiles for 11-year-old boys (Malina, Bouchard, & Bar-Or, 2004). Next, the relative parameters of the PF herein are calculated using the linear function of the BH and age (Knudson, Slatin Rc, Lebowitz, & Burrows, 1976). Such equations presume a linear increase of the PF variables with an increase of the BH, since lung volume, which naturally follows an increase of body proportions, is mostly defined by an increase of the BH. However, when the graphical presentations of the relationships between BH and PF are observed (see for example Boskabady, Tashakory, Mazloom, & Ghamami (2004), it is clear that the relationship is nonlinear. The linear calculation of the relative PF values practically penalizes persons whom are significantly taller than average (in our case, young basketball players), mostly because the body proportions in very tall subjects is not followed by proportional increases in other body proportions (diameters of the chest, for example). It is indirectly supported by numerous studies which introduced and studied the different allometric (nonlinear) calculations in human performance (Hoff, Kemi, & Helgerud, 2005; Markovic & Jaric, 2004; Sekulic, Zenic, & Markovic, 2005).

The significance of the differences in LAV, which was previously discussed, exists in SAV, where the E groups achieved significantly better results than the controls. However, the numerical differences between the two E groups previously noted in LAV variables are not so pronounced in SAV variables.

Nevertheless, all the differences we discussed so far are significant exclusively in the sub-sample of subjects who were not exposed to tobacco smoke (NS). More precisely, when comparing the passive smokers of the three groups (ES, EB, and C), we found no significant differences in PF. We will try to identify the possible reasons in the following text.

### *Pulmonary function in prepubescent passive smokers and non-exposed to passive smoking*

According to the presented data, and MANOVA calculations, passive smoking does not significantly influence PF in prepubescent boys. However, it cannot be ignored that the pulmonary variables of the PS subjects are regularly numerically (although not significantly) lower than NS subjects in all the three groups of subjects (ES, EB, and C). The nonsignificant differences in LAV and SAV status of PS, when compared to NS, are not unidentified so far. Although most of the previous studies reported a negative influence of passive smoking on the PF of the subjects (Cook, Strachan, & Carey, 1998), it is not rare to find studies in which a negative influence was not established, and/or the differences did not reach any appropriate level of statistical significance (Bek, Tomac, Delibas, Tuna, & Tezic, 1999), while others found a dose-effect relationship (Rizzi et al., 2004). Since most of the PF values were lower in PS, it seems reasonable to expect that after an extended length of time of exposure to passive smoking the differences between PS and NS will increase, and therefore will be significant in the future. Such a conclusion can be supported by previous studies in which the significant negative influence of passive smoking was regularly established when studying somewhat older children than those in our experiment (16 and 14 years in average) (Goic-Barisic et al., 2006; Rizzi et al., 2004). Another factor should be noted when explaining the nonsignificant differences between PS and NS in the studied samples of subjects in this paper. In 2006, Sekulic and Tocilj observed a non-systematic relationship in LAV and SAV for PS, when compared to NS. Briefly, the variables of the PF (LAV and SAV separately) are strongly correlated in NS exclusively, although those variables practically measure the same status and are influenced by the same processes. In explaining the relatively low correlation between PF variables in smokers, Sekulic and Tocilj (2006) presumed that passive smoking non-systematically negatively affects PF, defining the low correlation between the variables which should be systematically highly correlated. The mechanism of such a non-systematic influence of passive smoking remains unclear, but it is supposed that it depends on several factors including (1) dose-effects, (2) duration of the exposure to tobacco smoke, (3) artificially stimulated and shortened breathing in smokers, and/or (4) physical exercise. The first two mentioned factors are supposed to influence PF negatively, and the last two influence positively and partially diminish the negative effects of passive smoking on the PF. Following that idea, we additionally performed a factor analysis trying to establish the possible differences in the relationships between PF variables in PS, and NS. If such differences in the relationships exist in this studied sample of subjects (children), it will be a strong support to the previously discussed, since studies that suggested the problem of the non-systematic influence of the passive smoking were performed on adults.

TABLE 2 Factor analysis for the pulmonary function variables

| | PS | | NS | |
|---|---|---|---|---|
| | F1 | F2 | F1 | F2 |
| VCIN | 0.97 | 0.02 | 0.95 | 0.2 |
| FVC | 0.97 | 0.07 | 0.95 | 0.21 |
| FEV1 | 0.89 | 0.37 | 0.83 | 0.48 |
| PEF | 0.71 | 0.44 | 0.33 | 0.74 |
| MEF50 | 0.27 | 0.90 | 0.20 | 0.93 |
| MEF25 | 0.05 | 0.96 | 0.20 | 0.85 |
| Expl.Var | 3.25 | 2.05 | 2.68 | 2.45 |
| Prp.Totl | 0.54 | 0.34 | 0.45 | 0.41 |

Legend: PS - passive smokers, NS – non-exposed to passive smoking, VCIN - inspiratory vital capacity, FVC - forced vital capacity, FEV1 - forced expiratory volume in one second, PEF - peak expiratory flow, MEF50 - maximal expiratory flow after 50% exhalation, MEF25 - maximal expiratory flow after 75% exhalation; Expl.Var. - Variance explained, Prp.Totl. - Proportion of the total variance explained, F1 and F2 – factor structure

The results in Table 2 leave no doubt regarding the more coherent factor structure in the NS than in PS. Moreover, in the PS the PEF is projected on the F1 factor of the large airways function. In the NS sample, two very clear and easily interpretable factors are extracted, the F1 factor of the large airways function and the F2 factor of the small airways function. Since the factor analysis is elementary based on the correlation which exists between the different variables (Sekulic, Viskic-Stalec, & Rausavljevic, 2003) it is clear that conclusions from the previous studies regarding the non-systematic negative effect of passive smoking on the PF are supported herein. There is one more thing to support all that is said, and it relates to the variability of the results in the PS. It is clear that all the variables in the PS are more dispersed in comparison to the same variables in the NS subjects. Since the variability of the results determines the possibility of reaching the appropriate statistical significance of the differences (in our case, the significance of the differences between PS and NS), it is one more reason why we did not find any significant difference between PS and NS in any of the PF variables, although numerical differences of means are observable in most cases.

## Conclusions

The results of this study indicated significantly higher values of LAV and SAV in young athletes when compared to age-related controls, indicating a possible positive influence of physical exercise on the PF, affirming the first hypothesis of our study. It seems that the dynamic character of the basketball game has no differential effect on the PF when compared to the static character of dinghy sailing. Therefore, the second hypothesis of our study, in which we assumed more positive influence on the basketball game on the PF in boys, cannot be confirmed. Herein, we did not find any significant differences between passive smokers and examinees non-exposed to passive smoking in PF, probably because of the high variability of the results which did not allow reaching the acceptable level of significance. Moreover, we studied young children (11 years of age), while significant differences in the PF status between passive smokers and examinees non-exposed to passive smoking was previously regularly found for older children. Consequently, the third hypothesis of our study has to be rejected.



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There is certain evidence that the calculation of the relative PF values in children penalizes tall subjects, and should be revalidated. Further studies should define the longitudinal influence of sports training on the PF while precisely controlling sports selection and its influence on the PF results.

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