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Research Article

The Effects of Muscular Strength and Biochemical Parameters on Mallampati Classification in Elite Athletes and Non-athletes

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Abstract

Aim: This study aimed to undertake an anthropometric assessment and to compare the muscular strength of elite athletes with that of a control group to predict Mallampati classification.
Material and Method: The study group consisted of elite track athletes, and the control group consisted of volunteers with similar characteristics. Anthropometric measurements of the hand, fingers, and wrist were made; handgrip strength and the pinch strength of the fingers were also measured. A serum biochemical analysis was then performed. Participants were divided into two groups: those with Modified Mallampati Scores (MMS) I and II, and those with III and IV. A partial correlation test was used to examine the correlations of the variables according to the MMS groups.
Results: The study included 32 elite athletes and 42 volunteer participants. Serum Na level, fingertip to root digit 3 (FTR3), and FTR4 were significantly lower in males in MMS groups 3-4. Among all cases, wrist extension angle (WEA) was found to be significantly lower in MMS group 3-4. However, hand breadth at thumb (HBT), hand depth radial (HDR), breadth at the first joint of digit 2 (BFJD2), pinch strength of thumb (PST), and PSLF were significantly higher in MMS groups 3-4. Among these variables, HBT, BFJD2, PST, and PSLF were significantly higher in elite athletes, but HDR was similar between the study groups. MMS groups showed the highest correlation with the pinch strength of the thumb.
Conclusion: The pinch strength of the thumb and little finger was determined as the most important predictors for the MMS group rather than the handgrip strength (HGS).

Keywords: Modified Mallampati scores, handgrip strength, anthropometric measurements, elite athletes, difficult airway

INTRODUCTION

The unanticipated difficult airway is one of the worst scenarios in practice in anesthesia and reanimation due to potentially life-threatening events during anesthesia or acute airway management (1,2). A failed airway attempt is associated with several morbidity and mortality. Various office methods were suggested to use predicting the risk of the difficult airway in clinical evaluation before anesthesia intervention, but the accuracy and benefits of these remain unclear. Leading and well-studied tests included the Mallampati test, the modified Mallampati test, the Wilson risk score, the Cormack-Lehane test, thyromental distance, sternomental distance, mouth opening test, upper lip bite test, or any combination of these (1,3). A difficult airway means difficult facemask ventilation, difficult laryngoscopy, difficult tracheal intubation, and failed intubation. Unfortunately, all of these investigated index tests had relatively low sensitivities with high variability according to the current meta-analysis (2,4).

Although there have been significant developments and innovations with respect to airway management, such as video laryngoscopee and flexible fiberoptic intubation, difficult or failed intubation incidents are neither predictable norpreventable nor preventable (1). In addition to the physiological and metabolic characteristics of the case, the anthropometric evaluation of the airway and the associated factors that change anatomy affect airway management (5). Apart from the direct upper

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airway anatomy, individual characteristics such as age, gender, rare syndromes, and body mass index (BMI) that will indirectly affect this anatomy can make standard airway evaluation methods useless in some cases (6,7). Therefore, new diagnostic methods with higher sensitivity and specificity continue to be investigated (8,9). Lee et al. showed an inconsistency between the two most commonly used classificationsin obesity, Mallampati and Cormack-Lehane grades, and they indicate additional approaches or classification systems for the prediction of airway screening (8). Except for the head, neck, and upper airway, the relationship of some obesity-related anthropometric measurements with Mallampati scores has been previously studied (10). Weight and height are important parameters in the preoperative evaluation and these parameters differ significantly in elite athletes compared to the general population. Lean body mass, total muscle mass, and muscle strength are the most important features that can affect the airway and anesthesia intervention (11). Peck et al. (12) compared the risk for sleep-disordersbetween football linemen and other types of athletes and they detected a higher Mallampati index in the linemen group (2.2±0.8 vs 1.1±0.3). But, American football players are a specific group of athletes and the increased BMI is remarkable in this group (13). Track or endurance athletes have a higher lean body mass (muscle) so, it can be thought that Mallampati scores will be lower, or that the risk of a difficult airway may be lower (14). The negative effect of sarcopenia or the lossof muscle strength his seenin airway disease, andin chronic obstructive pulmonary diseases (15,16). Handgrip strength (HGS) is a standardized measure for assessing overall muscle strength and has been associated with restricted airflow in lung diseases (17). It can be predicted that airway management in track or endurance athletes will be simpler, but there are no studies in the existing literature on airway assessment or sleep disorders based on anthropometric measurements or muscle strength. This study aimed to conductanthropometric assessment and to compare the muscular strength of elite athletes withthat of the control group via Mallampati classification.

MATERIAL AND METHOD

Ethical Approval and Participants

An observational study was designed. The study was conducted in the Department of Anesthesiology, Faculty of Medicine, Ahi Evran University. Institutional ethics committee approval was obtained (2023-06/41). After written informed consent was obtained, 100 participants were enrolled in the study. The study group consisted of elite track athletes, while the control group consisted of volunteers with similar characteristics.

Eligibility Criteria

Elite athletes between the ages of 18-22 and volunteer participants in the same age range, of similar height and weight were included in the study. Participants with an inability to sit, macroglossia, a short frenulum, recent surgery of the head and neck, patients with severe cardiorespiratory disorders, patients with a dental prosthesis, or those who refused or were unable to give informed consent, were excluded from the study.

Outcome Parameters

In anthropometrics measurements height and weight were measured without shoes or heavy clothing to the nearest centimeter and 100 g, respectively. BMI was calculated as body weight in kilograms divided by height squared in meters. HGS tests were performed with a JAMAR® branded hand dynamometer to assess muscle power. Patients were placed seated on a chair with their hands were placed on a table. Their arms were held in a 90-degree flexion, parallel to the floor. Measurements of the dominant hand were then taken three times at 1-minute intervals. The average of three measurements was taken as the "low muscle strength",which was below 15 kg for males and 10 kg for females.

The modified Mallampati score (MMS; 1 to 4) was made by a single anesthetist with 5 years' clinical experience. The patients were divided into two groups: one group for MMS classes 1 and 2, and another group for MMS classes 3 and 4.

Hand anthropometric and muscle strength measurements (mm and kg) were as follows (18-21): hand length (HL), hand breadth at thumb (HBT), hand grip strength (HGS), wrist thickness, dorsal volar diameter (WTDVD), hand circumference (HC), wrist circumference (WC), hand depth radial (HDR), hand depth ulnar (HDU), fist circumference (FC), breadth/depth of digits 1 to 5 at the first and second joint (BFJD1-5, DFJD1-5, BSJD1-5, DSJD1-5), height of digits 1 to 5 (H1-5), palmar height of 1 to 4 (PH1-5), fingertip to root digit 1 to 5 (FTR1-5), total Length of digit 1 to 5 (TL1-5), span length of thumb-Index/middle/ring/little (SLTI-TM-TR-TL), pinch strength of thumb/index/middle/ring/little fingers (PST-M-R-LF), wrist radial abduction angle (WRAA), wrist ulnar abduction angle (WRAA), wrist flexion angle (WFA), wrist extension angle (WEA), thumb metatarsophalangeal flexion angle (TMFFA), and thumb interphalangeal flexion angle (TIFFA).

Laboratory Tests

Venous blood samples were collected for analysis after anthropometric measurements. Atomic absorption spectrometry and enzymatic / colorimetric methods were used for the serum biochemical analysis;copper (Cu, mg/dl), potassium (K, mEq/L), alanine aminotransferase (ALT, IU/L), aspartate aminotransferase (AST, IU/L), creatine kinase (CK, IU/L), high density lipoprotein (HDL, mg/dL), low density lipoprotein (LDL, mg/dL) lactate dehydrogenase (LDH, IU/L), triglyceride (TRIG, mg/dL), zinc (Zn, mg/dL), magnesium (Mg, mg/dL), iron (Fe, ug/dL), sodium (Na, mEq/L), and calcium (Ca, mg/dL).

Statistical Analysis

SPSS 25.0 and Modeler 18.0 (IBM Corporation, Armonk, New York, United States) programs were used in the analysis of the variables. The conformity of the data to the normal distribution was evaluated with the Shapiro-Wilk Francia test, while the homogeneity of variance was evaluated with the Levene test. Participants were divided into two groups, those with Mallampati scores I and II, and those with III and IV. The Independent-Sample t-test was expressed with Bootstrap results in the comparison of normally distributed quantitative variables according to Mallampati groups, and the Mann-Whitney U test was expressed with Monte Carlo results in the analysis of non-normally distributed variables. Pearson Chi-square and Fisher exact tests, and the Monte Carlo Simulation technique were used to comparethe Mallampati groups with each other according to gender and study groups. After controlling for the gender and study groups of the variables, the Partial Correlation test was used to examine the correlations of the variables according to the Mallampati score. For finding and estimating the variable with the highest significance of the Mallampati groups, supervised machine learning methods, Logistic regression, Support vector machine, Random forest, K-nearest neighbor algorithm, Simple (Naïve) Bayes Classification, C5 algorithm from decision trees and Neural network (Multilayer Perceptron-Radial) Basis was used. The results of the Neural Network (Multilayer Perceptron) analysis, which is the most successful model among these methods, were used. Gradient descent was used for the optimization algorithm, hyperbolic tangent was used as the hidden layer activation function, and Softmax was used as the output layer activation function. While quantitative variables were expressed as mean (standard deviation) and Median (Minimum-Maximum) in the tables, categorical variables were shown as n (%). The variables were analyzed at a 95%-confidence level and a p-value of less than 0.05 was considered significant.

RESULTS

The study included 32 (43.2%) elite athletes and 42 (56.8%) volunteer participants. Thirty-eight (51.4) of the participants were male. MMS was found to be MMS=1 in 31 (41.9) participants, MMS=2 in 22 (29.7%) participants, and MMS=3 in 20 (27.0%) participants. HGS was 37.5±12.6 kg in MMS 1 group, 44.2±15.0 kg in MMS group 2, and 45.5±12.9 kg in MMS group 3 (p=0.077). While WEA (0.010) was found to be significantly lower in MMS groups 3-4 in women, WC (0.049), HDR (0.021), PSLF (0.046) and TIFFA (0.004) were significantly higher. In males BMI (0.036) was found to be significantly higher in MMS groups 3-4, while Na (0.010), BSJD4 (0.030), H2 (0.049), FTR2 (0.030), FTR3 (0.022) and FTR4 (0.030) were significantly lower. Among all cases, WEA (0.010) was found to be significantly lower in MMS groups 3-4. Otherwise, BMI (0.021), HBT (0.049), FC (0.043), WC (0.013), HDR (0.010), BFJD2 (0.030), PST (0.003), PSLF (0.016) and TIFFA were significantly higher in MMS groups 3-4. Among these variables, HBT (<0.001), FC (0.002), WC (0.001), BFJD2 (0.001), PST (<0.001), and PSLF (<0.001) were significantly higher in elite athletes, but WEA (0.537), HDR (0.416) and TIFFA (0.528) were similar between study groups. All of the comparisons are given in Table 1. In addition, MMS groups showed the highest correlation with the pinch strength of the thumb (r=0.392, p=0.001, Table 2). According to the Multilayer Perceptron analysis, the most important factor for MMS groups in females was PSLF (100%), in males, fingertip to root digit 3 (FTR3) (100%) and among all participants, HBT (100%). According to this model, the variable with the lowest significance in the estimation of Mallampati in women, men or in total was determined as the study group (elite athlete vs. control, Table 3).

Table 2. The order of importance of the variables in MMS estimation, by gender and in total (%)

Total			Female			Male		
Variables	**Importance (%)**		**Variables**	**Importance (%)**		**Variables**	**Importance (%)**	
HBT	100.0		**PSLF**	100.0		**FTR3**	100.0	
WC	81.1		**TIFFA**	81.6		**Na**	96.5	
PST	77.2		**HDR**	77.2		**CSJD4**	91.8	
WEA	74.8		**WEA**	63.2		**H2**	87.1	
BFJD2	61.6		**WC**	13.6		**FTR2**	85.4	
PSLF	55.2		**Study group**	9.9		**BMI**	45.7	
HDR	35.4					**FTR4**	11.4	
Gender	15.5					**Study group**	6.1	
Study group	14.3							
Mallampati	**Predicted**								
	I+II	**III+IV**	**Correct (%)**	**I+II**	**III+IV**	**Correct (%)**	**I+II**	**III+IV**	**Correct (%)**
I+II	50	3	94%	28	1	97%	18	6	75%
III+IV	1	20	95%	1	6	86%	5	9	64%
Total	**69%**	**31%**	**95%**	**81%**	**19%**	**94%**	**61%**	**39%**	**71%**

HBT: hand breadth at thumb, WC: wrist circumference, PST: pinch strength of thumb, WEA: wrist extension angle, BFJD2: breadth at the first joint of digit 2, PSLF: pinch strength of little finger, HDR: hand depth radial, TIFFA: thumb interphalangeal flexion angle, FTR3: fingertip to root digit 3, CSJD4: circumference at the second joint of digit 4, H2: height 2, FTR2: Fingertip to root digit 2, BMI: body mass index, FTR4: fingertip to root digit 4

Neural Network (Multilayer Perceptron), Hidden layer activation function: Hyperbolic tangent output layer activaction function: Softmax, Dependent Variable: Mallampati

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Table 1. Multi-layered comparison of variables by study group (control and elite athlete) and gender

	Female		p	Male		p	Total		p
	(I+II)	(III+IV)		(I+II)	(III+IV)		(I+II)	(III+IV)	
	n (%)			n (%)			n (%)		
Gender (male)	-	-	-	-	-	-	24 (45.3)	14 (66.7)	0.125^c
Elite athlete	7 (24.1)	2 (28.6)	0.999^f	14 (58.3)	9 (64.3)	0.746^c	21 (39.6)	11 (52.4)	0.436^c
	Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)		
Height	1.65 (0.05)	1.65 (0.02)	0.784^t	1.74 (1.66-1.94)	1.74 (1.65-1.85)	0.244^u	1.68 (1.52-1.94)	1.70 (1.62-1.85)	0.501^u
Weight	59.06 (6.68)	59.51 (9.56)	0.883^t	82.05 (17.22)	83.86 (7.45)	0.713^t	64.20 (44-129)	78.10 (47-98.70)	0.052^u
BMI	20.98 (18.78-29.72)	21.30 (17.47-28.65)	0.872^u	24.66 (19.84-43.10)	28.05 (22.82-33.75)	**0.036^u**	22.27 (18.78-43.10)	25.50 (17.47-33.75)	**0.021^u**
Age	20 (19-22)	20 (18-21)	0.345^u	20 (18-27)	20 (18-26)	0.473^u	20 (18-27)	20 (18-26)	0.281^u
HL	173.23 (6.32)	173.32 (9.31)	0.990^t	191.26 (169.17-201.58)	185.52 (172.63-198.99)	0.100^u	177.62 (157.02-201.58)	181.92 (156.82-198.99)	0.532^u
HBT	74.85 (4.93)	75.90 (5.85)	0.640^t	87.34 (5.18)	87.69 (4.02)	0.812^t	80.50 (8.02)	83.76 (7.29)	**0.049^t**
HGS	28.68 (5.02)	29.61 (4.40)	0.630^t	54.36 (5.84)	53.52 (5.44)	0.634^t	34.90 (19.60-72.10)	50.30 (23.40-67)	0.173^u
Zn	0.78 (0.57-1.11)	0.66 (0.57-0.96)	0.216^u	0.84 (0.51-1.92)	0.90 (0.54-1.84)	0.292^u	0.81 (0.51-1.92)	0.88 (0.54-1.84)	0.567^u
Cu	0.93 (0.63-1.90)	0.96 (0.78-1.17)	0.608^u	0.78 (0.57-1.09)	0.80 (0.36-1.08)	0.985^u	0.84 (0.57-1.90)	0.87 (0.36-1.17)	0.913^u
Mg	24.90 (16.65-54.60)	22.50 (20.85-28.95)	0.636^u	26.73 (4)	26.69 (2.82)	0.970^t	26 (16.65-54.60)	25.80 (20.85-30.75)	0.879^u
Fe	1.50 (0.56)	1.56 (0.46)	0.810^t	1.89 (0.47)	2.01 (0.60)	0.475^t	1.67 (0.55)	1.86 (0.59)	0.218^t
K	142.50 (88.50-300)	160.50 (93-248)	0.874^u	241 (115-264)	234 (105-260)	0.522^u	165 (88.50-300)	174 (93-260)	0.791^u
Na	2946.81 (97.52)	2916.77 (146.54)	0.560^t	2927.47 (83.92)	2862.76 (84.85)	**0.010^t**	2938.05 (91.27)	2880.76 (108.64)	0.059^t
Ca	126.75 (57.88-382.75)	91.13 (46.63-147)	0.121^u	113.19 (26.87)	120.58 (25.88)	0.396^t	121 (57.88-382.75)	120.75 (46.63-182)	0.550^u
AST	17 (10-42)	14 (13-27)	0.623^u	22.33 (5.04)	20.79 (5)	0.317^t	18 (10-42)	18 (10-29)	0.721^u
ALT	15 (9-43)	14 (7-25)	0.541^u	20 (12-61)	17.50 (10-53)	0.375^u	16 (9-61)	17 (7-53)	0.945^u
CHO2	152.90 (28.08)	146.29 (16.78)	0.450^t	131 (90-241)	128.50 (109-206)	0.895^u	140 (90-241)	137 (109-206)	0.739^u
CK	70 (43-727)	75 (46-772)	0.977^u	119 (61-437)	113 (79-648)	0.216^u	102 (43-727)	102 (46-772)	0.727^u
HDL	60 (39.90-86.40)	57.60 (42.60-86.30)	0.931^u	53.95 (32-70.70)	55.75 (33.20-68)	0.982^u	55.85 (11.74)	56.05 (12.73)	0.941^t
LDL	97.68 (26.43)	83.93 (13.01)	0.070^t	88.78 (30.58)	90.39 (22.29)	0.871^t	93.65 (28.45)	88.24 (19.58)	0.356^t
LDH	155 (120-325)	148 (120-346)	0.744^u	189 (127-391)	145.50 (133-268)	0.145^u	157 (120-391)	147 (120-346)	0.237^u
TRİG	78 (34-271)	96 (47-143)	0.537^u	69 (50-232)	71 (64-452)	0.268^u	73 (34-271)	76 (47-452)	0.155^u
WTDVD	51.91 (48.91-77)	53.06 (44.74-58.04)	0.994^u	58.21 (51.23-67.72)	58.92 (52.58-63.58)	0.693^u	54.23 (48.91-77)	57.70 (44.74-63.58)	0.101^u
HC	73.19 (4.56)	73.57 (5.16)	0.900^t	83.50 (21-94)	85 (79-92)	0.957^u	79 (21-94)	81 (65-92)	0.096^u
WC	77.62 (6.30)	80.86 (3.13)	**0.049^t**	90.50 (22.50-107)	90 (72-106)	0.971^u	82 (22.50-107)	87 (72-106)	0.089^u
FC	94 (64-107)	94 (88-110)	0.567^u	109 (27-124)	110.50 (102-123)	0.730^u	99 (27-124)	107 (88-123)	**0.043^u**

HL: hand length, HBT: hand breadth at thumb, HGS: hand grip strength, WTDVD: wrist thickness, dorsal volar diameter, HC: hand circumference, WC: wrist circumference, FC: fist circumference

t: Independent t-test (Bootstrap), u: Mann-Whitney U test (Monte Carlo), f: Fisher exact test (Exact), c: Pearson Chi-square test (Monte Carlo, Exact)

Table 1. Multi-layered comparison of variables by study group (control and elite athlete) and gender

	Female		p	Male		p	Total		p
	(I+II)	(III+IV)		(I+II)	(III+IV)		(I+II)	(III+IV)	
	Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)		
WC2	61 (54-69)	63 (59-71)	0.401u	70 (17.50-83)	71.50 (64-78)	0.240u	63 (17.50-83)	70 (59-78)	**0.013u**
HDU	24.64 (2)	25.13 (2.92)	0.750t	29.47 (2.51)	28.56 (1.69)	0.178t	26.82 (3.29)	27.42 (2.67)	0.455t
HDR	41.68 (33.61-52.56)	47.33 (37.71-49.07)	**0.021u**	51.93 (4.62)	53.38 (3.30)	0.307t	46.57 (6.72)	51.01 (4.85)	**0.010t**
BFJD1	17.91 (1.11)	17.81 (1.59)	0.850t	20.95 (18.84-23.69)	20.73 (19.16-24.26)	0.549u	19.33 (1.97)	19.81 (1.97)	0.436t
DFJD1	15.18 (1.02)	15.40 (1.36)	0.760t	17.42 (1.32)	17.07 (1.27)	0.386t	16.20 (1.61)	16.52 (1.50)	0.485t
BFJD2	16.84 (12.54-19.09)	16.57 (14.96-20.08)	0.830u	19.04 (1.69)	19.48 (1.23)	0.376t	17.85 (1.85)	18.69 (1.81)	**0.030t**
DFJD2	14.87 (10.52-16.77)	15.48 (14.02-16.92)	0.484u	17.42 (1.27)	17 (0.95)	0.277t	16.09 (1.72)	16.49 (1.24)	0.347t
BSJD2	14.26 (13.09-15.79)	14.73 (13.09-17.23)	0.999u	16.19 (1.07)	16.23 (1.02)	0.931t	15.38 (13.09-17.96)	15.70 (13.09-18.17)	0.187u
DSJD2	11.58 (1.29)	11.50 (1.50)	0.900t	12.56 (11.49-15.23)	12.71 (9.93-14.80)	0.572u	12.26 (1.43)	12.21 (1.31)	0.950t
BFJD3	16.72 (0.94)	16.91 (1.88)	0.780t	19.33 (1.13)	19.06 (1.06)	0.545t	17.90 (1.66)	18.35 (1.69)	0.347t
DFJD3	15.34 (0.98)	15.93 (1.38)	0.340t	17.67 (1.61)	17.42 (0.94)	0.584t	16.40 (1.74)	16.93 (1.29)	0.178t
BSJD3	14.28 (0.90)	14.36 (1.60)	0.910t	16.45 (0.93)	16.19 (0.93)	0.396t	15.26 (1.42)	15.58 (1.45)	0.426t
DSJD3	11.69 (1.28)	11.73 (1.61)	0.970t	13.60 (1.16)	13.01 (0.82)	0.119t	12.55 (1.55)	12.59 (1.27)	0.960t
BFJD4	15.61 (0.76)	15.58 (1.42)	0.950t	18.22 (1.20)	18.23 (1.16)	0.990t	16.79 (1.63)	17.34 (1.77)	0.218t
DFJD4	14.37 (1.07)	14.65 (1.42)	0.710t	16.71 (1.18)	16.44 (1.23)	0.554t	15.43 (1.62)	15.84 (1.53)	0.347t
CFJD4	13.34 (9.49-15.32)	13.93 (12.16-16.13)	0.589u	15.25 (13.93-19.72)	15.41 (14.32-17.76)	0.588u	14.49 (1.82)	14.94 (1.35)	0.287t
BSJD4	10.63 (0.98)	10.76 (1.37)	0.850t	12.43 (1.01)	11.88 (0.67)	**0.030t**	11.45 (1.34)	11.50 (1.07)	0.911t
BFJD5	13.94 (1.23)	13.68 (1.76)	0.670t	15.64 (14.35-18.64)	15.92 (14.41-18.11)	0.450u	14.93 (1.63)	15.07 (1.63)	0.782t
DFJD5	12.47 (0.91)	12.29 (1.09)	0.800t	14.78 (1.17)	14.70 (1.31)	0.871t	13.52 (1.55)	13.90 (1.68)	0.455t
BSJD5	11.94 (0.73)	12.15 (1.18)	0.660t	13.76 (11.23-17.06)	13.89 (13-16.24)	0.932u	12.69 (9.96-17.06)	13.62 (10.55-16.24)	0.089u
DSJD5	9.44 (0.84)	9.54 (1.73)	0.890t	11.34 (1.30)	11.16 (0.99)	0.634t	9.93 (8.22-15.13)	10.99 (7.22-12.62)	0.193u
H1	81.34 (11.53)	76.66 (16.56)	0.450t	79.78 (12.15)	74.95 (9.99)	0.198t	80.63 (11.73)	75.52 (12.16)	0.129t
H2	163.51 (6.81)	161.15 (13.84)	0.670t	177.56 (9.54)	170.76 (7.55)	**0.049t**	169.87 (10.73)	167.56 (10.77)	0.495t
H3	173.37 (6.45)	173.74 (9.21)	0.930t	189.77 (8.80)	185 (4.18)	0.079t	180.80 (11.16)	181.25 (8.15)	0.881t
H4	164.50 (7.53)	161.99 (9.43)	0.490t	182.40 (161.41-192.39)	175.83 (165.72-183.75)	0.123u	170.91 (11.09)	169.96 (9.08)	0.733t
H5	134.07 (11.34)	129.68 (11.11)	0.360t	147.78 (10.78)	144.18 (9.52)	0.267t	140.28 (12.96)	139.34 (12.04)	0.772t
PH1	55.16 (4.25)	52.39 (8.27)	0.430t	55.81 (40.20-69.96)	61.81 (47.93-78.60)	0.115u	55.27 (5.60)	59.43 (11.47)	0.158t
PH2	97.41 (4.07)	96.65 (7.54)	0.780t	108.65 (95.62-155)	105.24 (98.28-111.09)	0.205u	101.43 (88.45-155)	104.45 (85.77-111.09)	0.427u

WC2: wrist circumference, HDU: hand depth ulnar, HDR: hand depth radial, BFJD1: breadth at the first joint of digit 1, DFJD1: depth at the first joint of digit 1, BFJD2: breadth at the first joint of digit 2, DFJD2: depth at the first joint of digit 2, BSJD2: breadth at the second joint of digit 2, DSJD2: depth at the second joint of digit 2, BFJD3: breadth at the first joint of digit 3, DFJD3: depth at the first joint of digit 3, BSJD3: breadth at the second joint of digit 3, DSJD3: depth at the second joint of digit 3, BFJD4: breadth at the first joint of digit 4, DFJD4: depth at the first joint of digit 4, CFJD4: circumference at the first joint of digit 4, BSJD4: breadth at the second joint of digit 4, BFJD5: breadth at the first joint of digit 5, DFJD5: depth at the first joint of digit 5, BSJD5: breadth at the second joint of digit 5, DSJD5: depth at the second joint of digit 5, H1: height1, H2: height2, H3: height3, H4: height4, H5: height5, PH1: palmar height of 1, PH2: palmar height of 2

t: Independent t-test (Bootstrap), u: Mann-Whitney U test (Monte Carlo), f: Fisher exact test (Exact), c: Pearson Chi-square test (Monte Carlo, Exact)

Table 1. Multi-layered comparison of variables by study group (control and elite athlete) and gender

	Female		p	Male		p	Total		p
	(I+II)	(III+IV)		(I+II)	(III+IV)		(I+II)	(III+IV)	
	Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)			Mean (SD.) or Median (min-max)		
PH3	97.98 (4.76)	98.59 (6.16)	0.840^{t}	107.69 (6.21)	106.79 (3.41)	0.673^{t}	102.38 (7.29)	104.06 (5.88)	0.188^{t}
PH4	87.01 (6.01)	86.41 (6.92)	0.840^{t}	97.67 (82.56-196.80)	95.05 (87.62-103.57)	0.533^{u}	90.65 (73.23-196.80)	93.25 (77.79-103.57)	0.495^{u}
FTR1	60.38 (4.28)	61.46 (5.49)	0.710^{t}	68.45 (5.12)	66.08 (3.78)	0.149^{t}	64.03 (6.16)	64.54 (4.83)	0.703^{t}
FTR2	69.93 (61.99-81.93)	71.18 (63.76-75.47)	0.297^{u}	74.79 (4.52)	71.37 (2.41)	**0.030^{t}**	71.82 (5.04)	71.12 (3.06)	0.455^{t}
FTR3	75.33 (3.36)	75.60 (3.29)	0.840^{t}	84.04 (72.64-91.45)	78.39 (73.01-80.83)	**0.022^{u}**	77.09 (65.36-91.45)	78.21 (69.74-80.83)	0.784^{u}
FTR4	70.01 (3.82)	70.07 (4.11)	0.970^{t}	76.39 (4.72)	73.07 (3.05)	**0.030^{t}**	72.90 (5.29)	72.07 (3.64)	0.337^{t}
FTR5	57.66 (3.43)	58.80 (5.13)	0.580^{t}	62.57 (3.84)	61.06 (3.30)	0.208^{t}	59.88 (4.36)	60.31 (4.02)	0.733^{t}
TTL1	124.33 (5.18)	126.14 (8.01)	0.490^{t}	134.23 (6.10)	134.09 (5.34)	0.960^{t}	128.81 (7.46)	131.44 (7.25)	0.079^{t}
TL2	169.36 (7.19)	169.94 (10.03)	0.890^{t}	182.75 (8.47)	178.89 (5.40)	0.089^{t}	175.43 (10.24)	175.90 (8.23)	0.782^{t}
TL3	174.35 (6.49)	173.38 (9.97)	0.880^{t}	189.26 (9.56)	184.90 (6.76)	0.129^{t}	181.10 (10.92)	181.06 (9.51)	0.990^{t}
TL4	164.86 (6.66)	164.24 (9.52)	0.930^{t}	179.45 (9.45)	176.71 (6.48)	0.386^{t}	170.24 (151.57-190.96)	172.25 (147.50-190.01)	0.449^{u}
TL5	142.61 (6.72)	141.70 (8.49)	0.790^{t}	155.30 (8.98)	153.97 (6.50)	0.634^{t}	148.36 (10.03)	149.88 (9.18)	0.495^{t}
SLTI	113.75 (10.94)	120.22 (15.57)	0.240^{t}	134.85 (114.03-174.60)	127.40 (114.14-155.25)	0.208^{u}	121.80 (91.06-174.60)	127.01 (99.96-155.25)	0.287^{u}
SLTM	149.78 (104.80-414.80)	161.04 (129.32-184.70)	0.113^{u}	177.59 (19.19)	168.55 (12.53)	0.079^{t}	159 (104.80-414.80)	164 (129.32-197.62)	0.335^{u}
SLTR	165.58 (12.29)	174.97 (17.38)	0.160^{t}	194.12 (21.28)	185.82(13.98)	0.228^{t}	175.54 (141.11-247)	185.70 (140.97-208.96)	0.205^{u}
SLTL	181.29 (13.21)	190.26 (17.83)	0.190^{t}	202.76 (16.99)	199.71 (10.05)	0.554^{t}	188.42 (148.29-233)	201.91 (157.07-212)	0.075^{u}
PST	10.25 (4.01)	14.40 (7.32)	0.290^{t}	19.42 (6.68)	24.09 (7.42)	0.119^{t}	13.60 (2.40-29)	19.80 (7.70-35)	**0.003^{u}**
PSIF	7 (2.34)	7.47 (2.79)	0.720^{t}	12.70 (4.60-22.70)	12.30 (9.10-22.30)	0.807^{u}	7.90 (3.50-22.70)	10.70 (3.20-22.30)	0.078^{u}
PSMF	6.96 (2.51)	7.66 (3.73)	0.660^{t}	12.47 (4.15)	12.19 (4.17)	0.839^{t}	8.40 (2.50-21.70)	10.40 (1.20-17)	0.175^{u}
PSRF	5.07 (1.45)	6.16 (2.54)	0.310^{t}	9.12 (4.14)	8.21 (2.21)	0.436^{t}	6.20 (1.70-19.60)	7.50 (2.30-11.60)	0.107^{u}
PSLF	2.60 (1.20-6.50)	3.90 (2.50-6.10)	**0.046^{u}**	5.87 (2.34)	6.03 (1.98)	0.851^{t}	3.40 (1.20-10.70)	5.50 (2.50-9)	**0.016^{u}**
WRAA	30.07 (5.97)	29.29 (6.37)	0.860^{t}	32.50 (24-46)	39 (16-45)	0.362^{u}	31.45 (5.91)	32.79 (9.37)	0.594^{t}
WRAA	33 (21-50)	34 (20-42)	0.746^{u}	40 (25-50)	43 (20-49)	0.983^{u}	40 (21-50)	40 (20-49)	0.886^{u}
WFA	60 (44-89)	65 (42-70)	0.886^{u}	69.55 (10.62)	76.22 (14.42)	0.168^{t}	65.08 (10.22)	70.43 (15.53)	0.139^{t}
WEA	78.06 (9.54)	67.14 (10.09)	**0.010^{t}**	70.75 (9.56)	67.53 (9.59)	0.386^{t}	74.75 (10.14)	67.40 (9.50)	**0.010^{t}**
TMFFA	55 (40-76)	55 (50-70)	0.469^{u}	60 (45-70)	62 (45-67)	0.895^{u}	60 (40-76)	60 (45-70)	0.312^{u}
TIFFA	78 (60-90)	87 (85-90)	**0.004^{u}**	85 (60-96)	84 (70-90)	0.831^{u}	80 (60-96)	85 (70-90)	**0.013^{u}**

PH3: palmar height of 3, PH4: palmar height of 4, FTR1: fingertip to root digit 1, FTR2: fingertip to root digit 2, FTR3: fingertip to root digit 3, FTR4: fingertip to root digit 4, FTR5: fingertip to root digit 5, TTL1: total thumb length, TL2: total length 2, TL3: total length 3, TL4: total length 4, TL5: total length 5, SLTI: span length thumb-index, SLTM: span length thumb-middle, SLTR: span length thumb-ring, SLTL: span length thumb-little, PST: pinch strength of thumb, PSIF: pinch strength of index finger, PSMF: pinch strength of middle finger, PSRF: pinch strength of ring finger, PSLF: pinch strength of little finger, WRAA: wrist radial abduction angle, WRAA: wrist ulnar abduction angle, WFA: wrist flexion angle, WEA: wrist extension angle, TMFFA: thumb metatarsophalangeal flexion angle, TIFFA: thumb interphalangeal flexion angle

t: Independent t-test (Bootstrap), u: Mann-Whitney U test (Monte Carlo), f: Fisher exact test (Exact), c: Pearson Chi-square test (Monte Carlo, Exact)

Table 3. Partial correlation table of MMS groups with variables

Mallampati*	r	p	Mallampati*	r	p	Mallampati*	r	p
Height	-0.200	0.092	HDU	-0.136	0.254	PH3	-0.091	0.448
Weight	0.010	0.936	HDR	**0.246**	0.037	PH4	-0.057	0.635
BMI	0.110	0.357	BFJD1	-0.071	0.551	FTR1	-0.129	0.281
Age	-0.043	0.717	DFJD1	-0.006	0.959	FTR2	-0.171	0.150
HL	-0.133	0.266	BFJD2	0.092	0.442	FTR3	-0.213	0.073
HBT	0.037	0.760	DFJD2	0.027	0.819	FTR4	-0.209	0.078
HGS	-0.052	0.665	BSJD2	0.037	0.758	FTR5	-0.031	0.793
Zn	0.025	0.833	DSJD2	-0.112	0.351	TTL1	-0.016	0.891
Cu	0.102	0.393	BFJD3	-0.058	0.630	TL2	-0.149	0.211
Mg	-0.125	0.296	DFJD3	0.069	0.564	TL3	-0.157	0.188
Fe	0.037	0.759	BSJD3	-0.009	0.943	TL4	-0.162	0.173
K	-0.010	0.931	DSJD3	-0.037	0.758	TL5	-0.093	0.436
Na	**-0.246**	0.037	BFJD4	-0.024	0.840	SLTI	-0.109	0.364
Ca	-0.129	0.281	DFJD4	0.013	0.915	SLTM	-0.003	0.983
AST	-0.048	0.687	BSJD4	0.041	0.731	SLTR	-0.056	0.641
ALT	-0.050	0.674	CSJD4	-0.101	0.398	SLTL	0.039	0.746
CHO2	0.007	0.952	BFJD5	-0.087	0.466	PST	**0.392**	0.001
CK	0.106	0.376	DFJD5	-0.079	0.512	PSIF	0.231	0.051
HDL	0.090	0.453	BSJD5	-0.028	0.814	PSMF	0.052	0.663
LDL	-0.138	0.249	DSJD5	-0.001	0.996	PSRF	0.006	0.958
LDH	-0.017	0.889	H1	-0.232	0.049	PSLF	0.131	0.273
TRİG	0.190	0.110	H2	-0.253	0.032	WRAA	-0.053	0.656
WTDVD	-0.038	0.751	H3	-0.128	0.285	WRAA	-0.077	0.520
HC	0.007	0.953	H4	-0.225	0.057	WFA	0.048	0.689
WC	0.051	0.671	H5	-0.196	0.099	WEA	**-0.277**	0.019
FC	0.066	0.581	PH1	0.095	0.429	TMFFA	0.145	0.225
WC2	0.053	0.656	PH2	**-0.240**	0.042	TIFFA	0.156	0.191

HL: hand length, HBT: hand breadth at thumb, HGS: hand grip strength, WTDVD: wrist thickness, dorsal volar diameter, HC: hand circumference, WC: wrist circumference, FC: fist circumference, WC2: wrist circumference, HDU: hand depth ulnar, HDR: hand depth radial, BFJD1: breadth at the first joint of digit 1, DFJD1: depth at the first joint of digit 1, BFJD2: breadth at the first joint of digit 2, DFJD2: depth at the first joint of digit 2, BSJD2: breadth at the second joint of digit 2, DSJD2: depth at the second joint of digit 2, BFJD3: breadth at the first joint of digit 3, DFJD3: depth at the first joint of digit 3, BSJD3: breadth at the second joint of digit 3, DSJD3: depth at the second joint of digit 3, BFJD4: breadth at the first joint of digit 4, DFJD4: depth at the first joint of digit 4, CFJD4: circumference at the first joint of digit 4, BSJD4: breadth at the second joint of digit 4, BFJD5: breadth at the first joint of digit 5, DFJD5: depth at the first joint of digit 5, BSJD5: breadth at the second joint of digit 5, DSJD5: depth at the second joint of digit 5, H1: height1, H2: height2, H3: height3, H4: height4, H5: height5, PH1: palmar height of 1, PH2: palmar height of 2, PH3: palmar height of 3, PH4: palmar height of 4, FTR1: fingertip to root digit 1, FTR2: fingertip to root digit 2, FTR3: fingertip to root digit 3, FTR4: fingertip to root digit 4, FTR5: fingertip to root digit 5, TTL1: total thumb length, TL2: total length 2, TL3: total length 3, TL4: total length 4, TL5: total length 5, SLTI: span length thumb-index, SLTM: span length thumb-middle, SLTR: span length thumb-ring, SLTL: span length thumb-little, PST: pinch strength of thumb, PSIF: pinch strength of index finger, PSMF: pinch strength of middle finger, PSRF: pinch strength of ring finger, PSLF: pinch strength of little finger, WRAA: wrist radial abduction angle, WRAA: wrist ulnar abduction angle, WFA: wrist flexion angle, WEA: wrist extension angle, TMFFA: thumb metatarsophalangeal flexion angle, TIFFA: thumb interphalangeal flexion angle

Partial Correlation Test, Control Variables: Study group & gender, r: Correlation Coefficient

DISCUSSION

The main findings of the study indicate that WEA was significantly lower in high MMS groups. In addition, BMI, HBT, FC, WC, HDR, BFJD2, PST, PSLF, and TIFFA were significantly higher in MMS groups. MMS groups showed the highest correlation with the PST. The most important factor for MMS groups in females was PSLF (100%), FTR3 in males, and HBT among all participants.

The Mallampati classification of the upper airway is based on the anatomical relation of the palatoglossal and palatopharyngeal arches, uvula, and the posterior part of the tongue. As such, if the volume or size of the base of the tongue is large, this limits the capacity of the oropharyngeal cavity (22). In addition, increased tongue thickness (TT), demonstrated even by neck ultrasonography, is an independent, proven risk factor for an increased risk of a difficult airway (Odd's Ratio=4.525 for TT>67 mm) (23,24). Wang et al. demonstrated strong correlations between tongue fat reduction and improvement in the apnea-hypopnea index (AHI), and they indicated that areduction in tongue fat affects tongue volume, increases the upper airway passage, improves tongue function, increased muscle strength, reduced and collapsibility of the tongue. The tongue is formed by extrinsic and intrinsic muscles, and the extrinsic muscles (the genioglossus, the hyoglossus, the styloglossus, and the palatoglossus) determine and change the position of the tongue in the oropharyngeal space (25). Current studies showed the efficacy of hypoglossal nerve stimulation as a major reason for hypopharyngeal obstruction with collapsed tongue base of the upper airway due to reduced genioglossus muscle tone (26). Similarly, myofunctional exercises of the local oropharynx region increase the mobility, endurance, and strength of the related muscles, and thus prevent the hypopharyngeal collapsing, especially the tongue base by forced repositioning (27). We could not find a study that directly assessed tongue/oropharyngeal muscle strength and mallampati scores or the risk of difficult airway intervention. However, with a general approach, a hypothesis such as 'Increasing muscle strength affects upper airway anatomy and functions similar to the effect achieved by reducing fat volume (decreased fat volume, and increased muscle function)' can be established. HGS has been suggested as a beneficial index for diagnosing overall muscular strength and sarcopenia in various conditions including nutritional status, muscle mass, walking performance, disabilities, and pulmonary function (15,17,28-31). Moreover, pinch strength reflects hand dexterity and is a more limited and specific issue. Pinch strength capabilities are generally associated with a response to rehabilitation after injuries, medicolegal reports with industrial accidents, specific athletic abilities, special sports branches, musculoskeletal and neurological diseases affecting dexterity, and industrial occupations/ergonomics (32). In the present study, contradictory to each other, PST and PSLF were found to be independent and important factors for difficult airway while the more commonly known HGS values did not show a significant relationship with MMS groups. Behavioral and neurophysiological studies support that the most stable grasp was obtained by jointly placing the index and middle finger as counterparts on the thumb (33,34). Furthermore, these three fingers constituted different types of pinch strength such as lateral pinch strength, key pinch strength, three-jaw chuck pinch strength, and tip-to-tip pinch, and both HGS with pinch strength of the fingers correlate to common anthropometric features including hand circumference, hand span, hand length, and palm length (35).

HGS and PSF are significantly higher in males and elite athletes, in keeping with the existing literature,with samples containing the same and different populations (36,37). HGS and PSF correlate with gender, age, height, weight, hand dominance, and BMI, and reach their peak between 25-29 years of age (38). Serum levels of CK, LDH, AST, and ALT are the most related markers of muscle volume and injury, so it is an expected finding that they are high in athletes and males. LDH is an important enzyme of the anaerobic metabolic pathway as oxidoreductase, and it catalyzes the reversible conversion of the lactate to pyruvate (39). Thus, increased serum levels have been demonstrated in sleep apnea and other ischemic conditions (40). However, given the association of OSAS or ischemic events with higher Mallampati classes in this situation, it would be expected that increased LDH levels would be associated with a higher MMS score. In this study, contrary to expectations, although a significant relationship between LDH and lower Mallampati scores was found, there is not enough evidence in the literature, and it is not realistic to declare LDH as a predictor for MMS with a limited sample size.

Limitations of the Study

The most important limitation of the study is the very small number of cases per sub-study group, for example, there was only one patient in the Mallampati class 4 group. In addition, it can be expected that the participants were not selected according to exercise intensity in the elite athlete group, and this would affect the laboratory parameters. Furthermore, ultimately, difficult airway is a clinical intervention, and planning a cohort study would be more appropriate for the methodology of such a study.

CONCLUSION

Clinically, PST and PSLF, which are variables expressing muscle strength, and FTR3 and HBT, which are anthropometric measurements, may be more useful because they both indicate elite athletes and correlate with high MMS groups. Contrary to the literature, the HGS muscle was not usable in this study because the analysis was made by controlling for gender and professional occupation affecting muscle strength.

In our study, the pinch strength of the thumb and little finger was determined as the most important predictor for the MMS group rather than HGS. Despite conflicting results, it may be recommended that elite athletes must be evaluated separately in their own groups in terms of anesthesia applications compared to other groups (for example, in the case of obesity).

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University. Institutional ethics committee approval was obtained (2023-06/41). After written informed consent was obtained, 100 participants were enrolled in the study. The study group consisted of elite track athletes, while the control group consisted of volunteers with similar characteristics.

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