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Cephalometric Soft Tissue Lip Measurements in Adults in Different Populations and Ethnic Groups: A Systematic Review

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Abstract

Objective: This systematic review aimed to collect and analyze available population data of soft tissue cephalometric lip measurements in adults.

Materials and methods: Cephalometric soft tissue norms measured by different analyses (Arnett, Bergman, Burstone, Ricketts, Holdaway, Steiner) were reported as values for their respective populations in this systematic review. Three databases (PubMed, Web of Science, EMBASE) were searched using MeSh and Emtree terms such as "cephalometry, reference norms, lip, orthodontics, orthognathic surgery, etc."

Results: The final number of full texts comprised of 24 studies. A total of 17 populations were studied and their respective cephalometric soft tissue lip measurements were collected. Different population/ethnic group cephalometric lip measurements were extracted to serve as reference standards for their respective populations.

B Caucasian population norms could not be applied as reference standards for other populations. There is a wide range of values for each cephalometric soft tissue lip measurement. The results of the reviewed studies can serve as reference standards for cephalometric lip measurements for their respective populations.

Keywords: Cephalometry; Lip;Population;Adult;Reference norms

Introduction

Soft tissue analysis has long been an undividable part of cephalometric analysis. Attempts to improve orthodontic treatment outcomes utilizing soft tissue analysis were made by Holdaway, Arnett, Ricketts, Legan and Burstone, Epker, and Steiner, whose analyses are most widely used[1-8].

The initial idea of equilibrium between the lips and tongue was by Robert M. Ricketts. To classify lip positions, Ricketts introduced the esthetic plane (E-plane). His research on the position of the lower lip was based on the perception of facial beauty of white adults with a 4 mm± 3 mm measurement. Holdaway claimed that 'ideal' dentoalveolar and skeletal results are not always associated with an improved facial profile. To assess the lower lip position, a Holdaway-plane was introduced.The upper lip in the Holdaway analysis was measured using two thickness parameters and a sulcus depth measurement. The ideal position for the lower lip relative to the H-line was set at 0.5 mm ±1.5 mm.

The importance of the upper lip position before treatment lies in the assessment of soft tissue lip changes following retraction of the upper incisors. The overall tendency of thickening of the upper lip following upper incisor retraction is a function of its initial strain, as stated by Ricketts[5].

Merrifield[9] came up with a similar idea of a profile line, which was tangent to the soft tissue pogonion and the most procumbent lip. While the Holdaway H-line touches the upper lip and intersects the SN line, the Tweed-Merrifield's profile line touches the most procumbent lip and intersects the Frankfort horizontal (FH) plane. The upper lip thickness was higher in men (14.4 mm)than that in women (13.4 mm) with a broader range in female subjects (13-16 mm in men and 9-18 mm in women).

Burstone introduced two lip posture definitions: the relaxed lip posture and the closed-lip posture. The former is a muscle-dictated position and does not rely on hard tissues. Burstone measured the average dimensions of the interlabial gap in adolescents with acceptable faces, which were 1.8 mm in the centric occlusion and 3.7 mm in the relaxed lip position. The method of measuring the length of the upper and lower lips suggested by Burstone includes the subnasale-upper stomion distance for the upper lip and lower stomion-gnathion for the lower lip. Burstone did not find any difference between the length

of the upper lip in adolescents with Class II,division1 malocclusion and that in Class I, normal face subjects.A nasolabial angle was also introduced to measure the relative position of the upper lip to the nose with an average of 74 degrees in Class I adolescents[8].

In a photogrammetric study of profile measurements in the African-American population, Sushner found that the values of upper and lower lip positions relative to the E-line, H-line, S-line, and nasion-pogonion line were significantly more protrusive in males than that in females compared to Caucasian norms by Ricketts, Holdaway, and Steiner[10].

Farkas measured the upper and lower lip dimensions using direct anthropometry, namely on live subjects, compared to cephalometric and photogrammetric measurements. Farkas confirmed that the upper lip occupies a third of the lower third of the face. The author also suggested measuring the vertical dimension of the lower lip with the supramentale point as the inferior border compared to the gnathion[11].

A study by Peck and Peck using anthropometric measurements of soft tissues in the frontal and sagittal planes described similar findings of longer upper lips in male subjects compared to that in female subjects, corresponding to the cephalometric measurement results obtained by Burstone. Interlabial gap measurements with lips at rest had values of 3.3 mm and 2.6mm in females and males, respectively, which is higher than those reported by Burstone[12].

Arnett was among the first to emphasize the difference between head position oriented relative to FH plane compared to the natural head position (NHP), as described by Showfety[3,13]. Arnett introduced soft tissue analysis based on obtaining cephalometric films in the NHP, with condyles seated in a centric relation and lips relaxed.

This systematic review aimed to gather the existing population-based measurements of the lips using different soft tissue analyses and create a reference for respective measurements in different populations.

Materials and Methods

Study protocol

The study protocol was registered in advance at the International Prospective Register of Systematic Reviews.

The following databases were searched: PubMed, Embase,and Web of Science. Manual searches included bibliographies of included studies, original studies, and studies that were not available in electronic databases. The search was conducted from July 9th to August 21st, 2020. The key words included "population groups,""orthodontics,""cephalometry,""lip,""referen ce standards,""reference values,"etc. The database search strategy used for PubMed is reported in the Appendix.

The PubMedsearch yielded 12005 articles; Embase, 7233 articles; and Web of Science,278 articles. The search results were downloaded and imported into the reference management software,"Mendeley," where duplicate articles were removed. After the complete search, the total number of articles to be reviewed was 10491. The applied inclusion and exclusion criteria included studies of untreated samples with balanced faces, Class I canine and molar relationship, no missing teeth except for third molars, no systemic diseases, no allergies, no pregnancy, no history of orthodontic treatment, no history of maxillofacial trauma, no prosthetic restorations, no orthodontic retainers, subject`s age 18 years old and over, male and female subjects, various populations/ethnic groups, type of intervention: cephalometric measurements.

The resultant 64 full texts were screened using the same inclusion and exclusion criteria by two researchers independently and crosschecked by a third reviewer. Out of the 64 full-text articles, 40 were excluded based on the inclusion of adolescent or subjects under 18 years old, or no age specification, and use of methods other than cephalometric assessment (3D scanner)(Figure 1).

Twenty-four resultant full texts represented 17 populations/ ethnic groups. The following populations/ethnic groups were reported in the selected studies: Bangladeshi, Chinese, AfricanAmerican, European American, Indian, Iranian, Japanese, Korean, Malay, Mexican, Nigerian, Pakistani, Persian, Saudi, Turkish, Malaysian Chinese, and Malaysian Indian. The analyses used in the studies were as follows: Arnett, Burstone, Steiner, Ricketts, Holdaway, and Epker analysis. A summary of the 24 studies is presented in Table 1.

Assessment of bias

The ROBINS-I tool[14].was used to analyze and detect biases in the following studies.

Based on the data from 24 full-text articles, confounding, patient selection, and bias in measurement outcomes were the most prevalent. Among the confounding factors, head position, condylar position, lip posture, and pre-screening lateral cephalograms contributed to the critical level of the respective domain. For outcomemeasurement, a critical level of bias was achieved in instances with subject awareness and examiner awareness of the outcomes of the intervention (cephalometric measurement of soft tissues of the lip).

Cephalometric linear and angular soft tissue lip measurements were the variables considered in this review.

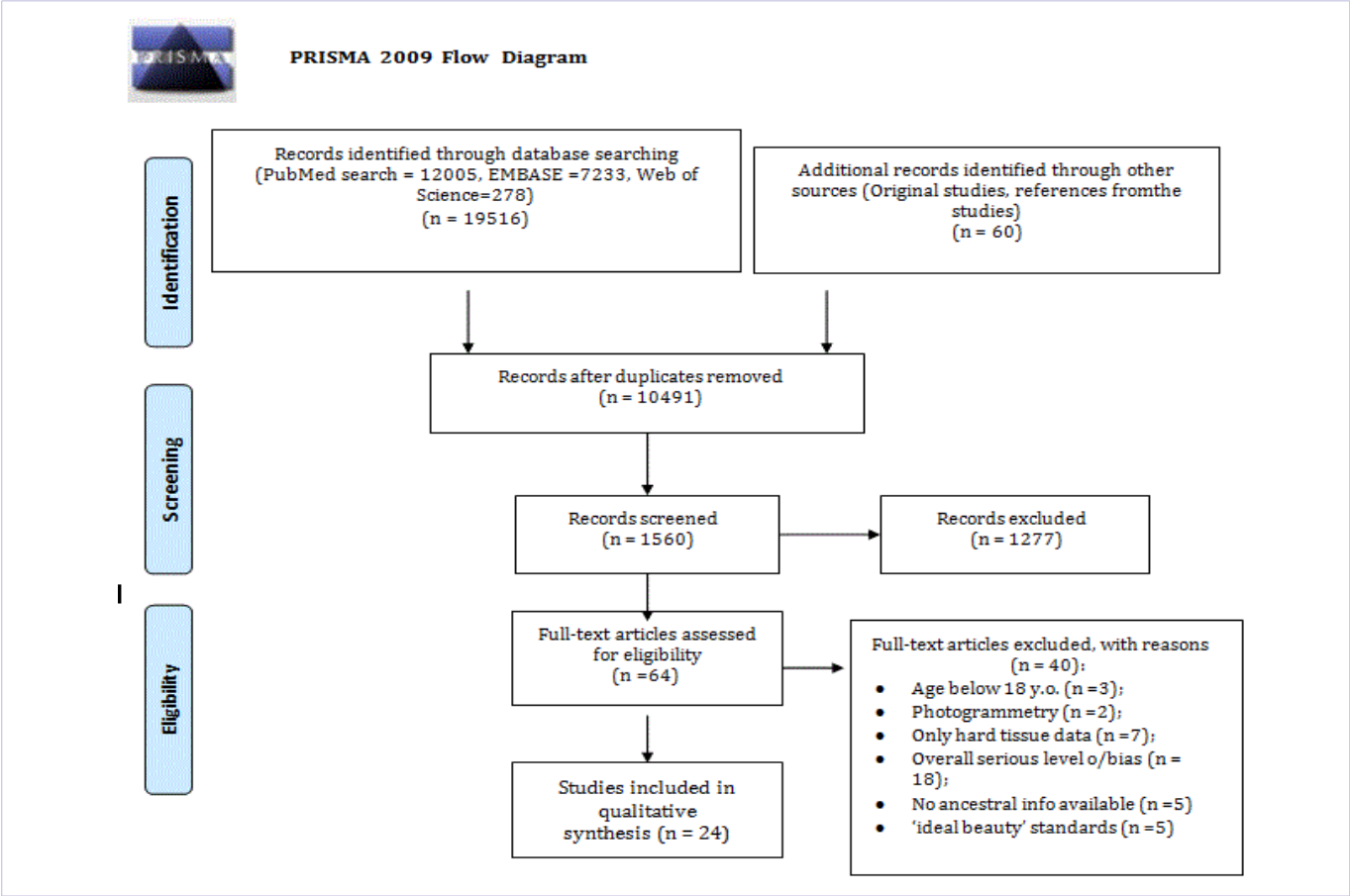

Figure 1: PRISMA flow diagram

#	Author	Year	Population/ethnic group	Sample size		Mean age, years	Analysis used
				# males	# females		
1	Sinojiya et al.	2014	Mahabubnagar population io Southern India	30	30	21.3	Arnett/Bergman
2	Miyajima et al.	1996	Japanese (1) and European-American (2)	(1)26; (2)44	(1)28; (2)81	(1) 22.5; (2) 37.5	McNamara
3	Bacon et al.	1983	African Bantu (1), Caucasoid (2)	(1)40; (2)40	-	(1) 25; (2) 25.	Ricketts
4	AlBarakati	2011	Saudi	31	30	23	Legan/Burstone
5	Purmal et al.	2012	Malaysian Indian (1), Malaysian Chinese (2)	(1)97; (2) 98	(1)21.7; (2)22.2	23.5	Burstone
6	Hashim et al.	2003	Saudi	30	26	22.5	Ricketts, Burstone
7	Siddika et al.	2020	Saudi	250	250	25	Ricketts
8	Khan et al.	2016	Pakistani	50	50	20	Ricketts, Steiner, Burstone
9	Yadav et al.	2011	Central Indian	38	38	24	Legan/Burstone
10	Isiekwe et al.	2012	Nigerian	56	44	21.36	Burstone
11	Basciftci et al.	2004	Anatolian Turkish	50 (1)	50 (2)	(1)22.61±1.22; (2)22.14±1.44	Ricketts, Steiner, Holdaway

12	Rakhshan et al.	2019	Iranian	45	85	22.77±2.55	Ricketts, Holdaway, Burstone,Epker
13	Isiekwe et al.	2012	Nigerian	44	56	23	Steiner, Ricketts, Burstone, Holdaway
14	Uysal et al.	2011	Turkish (1), Saudi (2)	(1.1)41; (2.1)38	(1.2)45; (2.2)39	(1.1)21.6±2.7; (1.2)20.1±3.1; (2.1)22.4±2.1; (2.2)20.6±3.4	Holdaway, Ricketts, Steiner
15	Alam et al.	2013	Bangladeshi	50	50	20	Burstone
16	Celebi et al.	2013	Turkish	48 (1)	48 (2)	(1)-22.6; (2)-21.4	Legan/Burstone
17	Park et al.	1989	Korean	35	45	18	Steiner
18	Alfarra et al.	2018	Malay	-	62	28	Holdaway
19	Swlerenga et al.	1994	Mexican-American	23	25	34	Burstone
20	Arora et al.	2018	South Indian	30	30	23	Arnett
21	Connor et al.	1985	North American Black (1), North American White (2)	(1)25; (2)25	(1)-25; (2)-25	23.5	Burstone
22	Al Taki et al.	2009	Persian	28 (1)	34 (2)	(1)-22±0.8; (2)-21±0.5	Holdaway
23	Thomas et al.	2010	Lambada	25	25	25	Holdaway
24	Choi et al.	2000	Korean	-	43	21.5	Arnett

Results

The results of this study are presented in four tables with the data arranged by population and analysis used (Arnett-Bergman, Ricketts, Holdaway, Steiner, and Burstone)(Tables 2-5).

Population-based studies showed several pronounced differences between the respective populations and Caucasian norms.

Thus, Saudi population was shown to have more protruded lips with significant gender dimorphism where male subjects showed more protrusion. Saudi female subjects were also shown to have shorter lower lip, shorter distance between the nasal tip and the most protrusive lip[15-17].

In Turkish and Anatolian population studies [18,19],Ricketts and Steiner measurements of the upper lip were found to be lower than for Caucasians (Table 3, 5), larger nasolabial angle, smaller interlabial gap (Table 2).

Persian population has greater basic upper lip thickness with significant differences between sexes [20](Table 4). Iranian population showed more retruded upper lip relative to E-plane (Table 3), lower upper lip thickness, smaller interlabial gap (Table 2), although the upper lip strain, upper lip curvature were greater in Iranian population compared to the Caucasian norms (Table 4) [21].Pakistani population norms showed significant sex dimorphism between male and female subjects with male subjects having larger nasolabial angle and upper lip thickness than female subjects (Table 2). [22].

South Indian population soft-tissue measurements showed intersexual differences with male subjects having thicker lips than female subjects[23]. Central Indian population was shown to have greater upper and lower lip protrusion than Caucasian population (Table 2) [24], in South-Eastern Indian population male subjects were shown to have more acute nasolabial angle than female subjects; maxillary incisor exposure was greater in female subjects (Table 2)[25]. In Bangladeshi population adult male subjects have more protruded lips compared to Bangladeshi female subjects[26].

Studies of Korean population showed interracial differences compared to Cacasian norms in several parameters, upper lip length, interlabial gap, upper incisor exposure, nasolabial angle[27]. Upper and lower lips were shown to be more protruded in Korean subjects compared to Caucasians[28]. In the study comparing European-American and Japanese population it was shown that Japanese men and women had more protrusive upper and lower lips[29].

Studies of American Black population showed significantly smaller nasolabial angle values than in Caucasian subjects [30]. In Nigerian population upper lip protrusion measured with Ricketts, Steiner, and Burstone analyses, was shown to be larger

Table 2: Arnett measurements

	1		2(1)		2(2)		3	
	M	F	M	F	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip thickness (Arnett, Burstone)	11.2±0.98	9.68±1.01						
Lower lip thickness (Arnett, Burstone)	12.75±1.09	11.52±0.88						
Nasolabial angle	100.4±1.59	103.4±5.94	90.7±10.4	92.2±8.7	102.4±8.2	102.2±7.7	102.85±11.1	109.68±10.2
Upper lip angle (Arnett)	10.41±2.47	8.66±1.28						
Upper lip length (Arnett, Burstone)	17.83±1.32	16.93±1.86						
Interlabial gap (Arnett, Burstone)	0.38±0.58	0.6±0.97					2.69±1.24	1.73±0.58
lower lip length (Arnett, Burstone) (LLs - Me`)	39.87±2.89	37.6±1.91						
Upper lip anterior to TVL (Arnett)	1.47±1.19	1.13±0.89						
Lower lip anterior to TVL (Arnett)	-0.48±1.86	-0.52±1.64						

	4(1)	4(2)	M	F	general	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip thickness (Arnett, Burstone)						15.06±1.67	10.93±1.99
Lower lip thickness (Arnett, Burstone)						18.45±2.26	15.97±2.37
Nasolabial angle	98.6±14.14	102.1±2.41	102.06±3.42	103.4±3.42	102.19±7.5		
Upper lip angle (Arnett)							
Upper lip length (Arnett, Burstone)						25.58±3.11	23.66±2.31
Interlabial gap (Arnett, Burstone)	0.19±1	0.19±0.56					
lower lip length (Arnett, Burstone) (LLs - Me`)						47.83±4.53	45.56±4.07
Upper lip anterior to TVL (Arnett)							
Lower lip anterior to TVL (Arnett)							

	M	F	M	F	10(1)	10(2)	10(3)	10(4)
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip thickness (Arnett, Burstone)								
Lower lip thickness (Arnett, Burstone)								
Nasolabial angle	101.11±11.32	101.27±10.26	103.4±13.02	105.27	107.05±8.45	105.7±9.5	108.4±7.4	106.02±8.24
Upper lip angle (Arnett)								
Upper lip length (Arnett, Burstone)	23.5±2.94	20.28±2.2						
Interlabial gap (Arnett, Burstone)	0.91±0.29	1.02±0.45			1.1±1.55	1.1±1.4	1.1±1.7	2.24±0.93
lower lip length (Arnett, Burstone) (LLs - Me`)								
Upper lip anterior to TVL (Arnett)								
Lower lip anterior to TVL (Arnett)								

than in Caucasian population[31].

Ricketts upper and lower lip position to E-plane was used as a measurement in 12 population studies. The position of the upper lip relative to E-plane had a wide range from -6.4 ± 2.4mm in European-American male subjects and -5.7 ± 1.9 mm in European-American female subjects to 4.07 ± 2.66 mm in Nigerian male subjects and 2.54 ± 2.54 mm in Nigerian female subjects.

Ricketts lower lip position relative to E-plane had a range from-4.3 ± 2.4 mm in European-American male subjects to 7.88 ± 2.7 mm in Nigerian male subjects, and from -3.2 ± 2 in European-American female subjects to 5.88 ± 2.64 mm in Nigerian female subjects.

	11		12		13	
	M	F	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip thickness (Arnett, Burstone)					12.58±0.94	10.7±1.04
Lower lip thickness (Arnett, Burstone)					13.18±1.18	11.51±1.09
Nasolabial angle			94.3±10.56	100.24±8.38	97.45±7.29	95.43±5.59
Upper lip angle (Arnett)						
Upper lip length (Arnett, Burstone)	29.2±2.1	28.3±1.9	24.4±1.72	23.56±1.56	19.96±1.89	17.81±1.94
Interlabial gap (Arnett, Burstone)					0.51±0.72	0.51±0.68
lower lip length (Arnett, Burstone) (LLs - Me`)			51.04±3.44	47.96±2.84	43.33±3.17	39.81±2.6
Upper lip anterior to TVL (Arnett)						
Lower lip anterior to TVL (Arnett)						

	14				15
	14(1)	14(2)	14(3)	14(4)	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip thickness (Arnett, Burstone)					12.19±1.39
Lower lip thickness (Arnett, Burstone)					13.63±1.36
Nasolabial angle	101.19±11.95	107.34±7.33	76.27±18.01	77.05±15.25	90.36±8.1
Upper lip angle (Arnett)					
Upper lip length (Arnett, Burstone)	24.13±2.59	21.5±3.55	27.72±2.46	26.34±2.89	24.14±1.69
Interlabial gap (Arnett, Burstone)					1.52±6.03
lower lip length (Arnett, Burstone) (LLs - Me`)	49.2±3.14	47.13±2.4	50.94±3.6	49.52±3.89	46.84±6.37
Upper lip anterior to TVL (Arnett)					4.91±1.41
Lower lip anterior to TVL (Arnett)					2.45±1.64

M – male, F – female. 1 – Sinojiya et al, 2014, Mahabubnagar population; 2(1) – Miyajima et al., 1996, Japanese population, 2(2) - Miyajima et al., 1996, European-American population; 3 – AlBarakati, 2011, Saudi population; 4(1) – Purmal et al., 2012, Malaysian Indian population, 4(2) – Purmal et al., 2012, Malaysian Chinese population; 5 – Khan et al., 2016, Pakistani population; 6 Yadav et al., 2011, Central Indian population; 7 – Isiekwe et al., 2012, Nigerian population; 8 – Rakhshan et al., 2019, Iranian population; 9 – Alam et al., 2013, Bangladeshi population; 10 – Celebi et al., 2013, 10(1) – Turkish population in general, 10(2) – Turkish males, 10(3) – Turkish females, 10(4) – Saudi population in general; 11 – Park et al., 1989, Korean population; 12 – Swelerenga et al., 1994, Mexican-American population; 13 – Thomas et al., 2010, Lambada population; 14 – Connor et al., 1985, 14(1) – White males, 14(2) -White females, 14(3) – Black males, 14(4) – Black females; 15 – Choi et al., 2000, Korean females.

Nasolabial angle was commonly used in conjunction with Arnett measurements and Burstone analysis. The lowest values were reported in Black male and female subjects, 76.27 ± 18.01 mm and 77.05 ± 8.45 mm, respectively. The highest values are found in Saudi females, 109.68 ± 10.02 mm.

Table 3: Ricketts measurements

	1(1)		1(2)		2		3		4	
	M	F	M	F	2(1)	2(2)	3(1)	3(2)	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip to E-Plane	-2.9±2.2	-2.5±1.9	-6.4±2.4	-5.7±1.9			-2.09±1.02	-0.43±1	-4.3±2	-3.9±1.9
Lower lip to E-plane	-0.3±2.6	0.9±0.9	-4.3±2.4	-3.2±2	4.9±1	-4.1±1	0.13±0.99	1.66±0.91	-2.2±2.5	-1.5±2
	5		6		7		8		9	
	M	F	M	F	M	F	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip to E-Plane	-2.024±3.584	-2.003±2.788	1.6±0.885	1.16±0.885	-4.97±2.55	-5.03±2.09	-5.4±2.03	-5.01±2.17	4.07±2.66	2.54±2.54
Lower lip to E-plane	2.516±4.043	1.84±3.04	-0.73±1.105	-0.7±1.105	-2.7±2.98	-2.7±2.27	-2.19±2.48	-2.28±2.48	7.88±2.7	5.88±2.64
	10				11		12			
	10(1)	10(2)	10(3)	10(4)	M	F	M	F		
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD		
Upper lip to E-Plane	-6.1±2.2	-5.8±2.5	-3.8±2	-4.1±1.9	1.86±1.54	2.12±1.54	0.7±2.7	0.2±1.7		
Lower lip to E-plane	-3.4±2.5	-2.6±2.2	-0.3±2.4	-1.7±1.6	-0.26±1.26	-0.01±1.26				

1 – Miyajima et al., 1996, 1(1) – Japanese population, 1(2) – European-American population; 2 – Bacon et al., 1983, 2(1) – African Bantu population (males only), 2(2) – Caucasoid population (males only); 3 Purmal et al., 2012, 3(1) – Malaysian Indian, 3(2) – Malaysian Chinese; 4 – Hashim at al., 2003, Saudi population; 5 – Siddika et al., 2020, Saudi population; 6 – Khan et al., 2016, Pakistani population; 7 – Basciftci et al., 2004, Anatolian Turkish; 8 – Rakhshan et al., 2019, Iranian population; 9 – Isiekwe, 2012, Nigerian population; 10 – Uysal et al., 2011, 10(1) – Turkish males, 10(2) – Turkish females, 10(3) – Saudi males, 10(4) – Saudi females; 11 – Alam et al., 2013, Bangladeshi population; 12 – Park et al., 1989, Korean population.

Table 4: Burstone measurements and Holdaway measurements

	1		2		3		4	
	M	F	2(1)	2(2)	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip protrusion (Burstone)	4.24±1.53	3.39±1.61			10.72±2.11	9.15±1.99	5.53±0.87	5.31±0.87
Lower lip protrusion (Burstone)	3.63±2.22	2.84±1.91			11.6±2.62	9.69±1.84	4.23±1.1	4.04±1.1
Mentolabial sulcus (Burstone)	4.85±1.17	4.32±1.32						
Vertical lip-chin ratio (Burstone)	0.44±0.06	0.46±0.05						
Mx1 to bottom of upper lip	3.18±2.48	3.37±1.38	2.24±1.99	0.16±0.78				
LLA			118.65±3.93	144.7±1.21				

	5			6		7
	5(1)	5(2)	5(3)	M	F	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Upper lip protrusion (Burstone)	3.35±1.9	3.9±1.7	2.8±2.1			
Lower lip protrusion (Burstone)	2.25±1.75	2.4±1.9	2.1±1.6			
Mentolabial sulcus (Burstone)	-5.65±1.6	-5.4±1.6	-5.9±1.6			
Vertical lip-chin ratio (Burstone)	0.48±0.075	0.47±0.1	0.49±0.05			
Mx1 to bottom of upper lip				2.85±1.08	2.56±1.22	2.73±1.17
LLA						

	8		9		10	11		12	
	M	F	M	F	females only	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Superior sulcus depth (Holdaway)			4.99±1.64	4.6±1.15	3.1±1.74	3.66±1.06	3.21±1.16	3.94±1.28	3.82±0.99

									9
Sof tissue subnasale to H-line (Holdaway)			5.19±2.25	4.07±2.08		5.93±1.99	5.53±1.92	5.94±2.03	5.14±1.66
Basic upper lip thickness (Holdaway)			16.93±2.67	13.64±2.17	12.68±0.63	18.09±2.21	15.25±1.81	16.42±1.29	13.08±1.55
Upper lip strain (Holdaway)			14.77±2.65	11.94±1.89	14±1.92	15.59±2.9	12.37±2.02	2.5±1.61	2.44±1.53
Lower lip to H-line (Holdaway)	0.6±1.59	0.5±0.4	1.17±1.47	0.75±1.59	1.65±1.94	0.57±1.74	1.28±1.72	1.44±1.16	1.58±1.5
Inferior sulcus to H-line (Holdaway)					4.88±2.91	6.63±1.95	4.19±1.93	5.62±1.19	4.52±1.7

1 – AlBarakati, 2011, Saudi population; 2 – Purmal et al., 2012, 2(1) – Malaysian Indian, 2(2) – Malaysian Chinese; 3 – Isiekwe et al., 2012, Nigerian population; 4 – Alam et al., 2013, Bangladeshi population; 5 – Celebi et al., 2013, 5(1) – Turkish population in general, 5(2) – Turkish males, 5(3) -Turkish females; 6 – Arora et al., 2018, South Indian population; 7 – Choi et al., 2000, Korean females, 8 – Basciftci et al., 2004, Anatolian Turkish; 9 – Rakhshan e al., 2019, Iranian population; 10 – Alfarra et al., 2018, Malay females; 11 – Al Taki et al., 2009, Persian population; 12 – Thomas et al., 2010, Lambada population.

Table 5: Steiner measurements

	1		2		3	
	M	F	M	F	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Ls- S1 (Steiner)	4.55±0.565	4.5±0.565	-2.17±2.18	-2.33±1.82	6.77±2.33	5.19±1.9
LL -S1 (Steiner)	3.42±0.926	3.51±0.926	-1±2.47	-0.8±1.78	9.02±2.74	7.54±2.3
	4				5	
	4(1)	4(2)	4(3)	4(4)	M	F
	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD	mean±SD
Ls- S1 (Steiner)	-1.8±1.8	-2±2	-0.3±1.7	-1±1.6	0.4±2.1	1.6±1.7
LL -S1 (Steiner)	-0.8±2.3	-0.3±1.9	1.8±2.3	0.4±1.5	-0.7±2.7	-0.2±1.7

1 – Khan et al., 2016, Pakistani population; 2 – Basciftci et al., 2004, Anatolian Turkish population; 3 – Isiekwe et al., 2012, Nigerian population; 4 – Uysal et al., 2011, 4(1) – Turkish males, 4(2) – Turkish females, 4(3) – Saudi males, 4(4) – Saudi females; 5 – Park et al., 1989, Korean population.

Discussion

This systematic review aimed to collect and analyze relevant, unbiased data on cephalometric lip measurements in adults from published studies of 17 populations and ethnic groups described in 24 studies.

The methodology of collecting lateral cephalometric radiographs differed from study to study, with major distinctions in the head, condylar, and lip position during radiographic exposure. The NHP, initially described by Showfety andVig[13],was used to take cephalometric radiographs for Arnett[3] and Legan-Burstone analyses[8]. The majority of studies implementing Arnett and Legan-Burstone analyses used lateral cephalograms taken in the NHP with teeth in the maximum intercuspal position (MIP) and lips repose or slightly closed[16-19,27,31,32]. Several studies used cephalograms taken with the head in the NHP, condyles seated, and lips relaxed[23,25]. Some studies had their subjects' heads oriented to the FH plane with teeth in the MIP, lips relaxed or lightly closed[18,25,33-35]. Several studies either did not specify the head orientation of their subjects during exposure[15,20,28,30,36-38]or used cephalometric radiographs retrospectively[21].

The nasolabial angle (NLA), as described by Burstone[8],is a horizontal indicator of the upper lip position. Although the angle follows a dentoskeletal pattern, and acute angles are largely found in Class II,division 1 subjects, this angle can be affected by both the position of the nose tip and the thickness of the upper lip. Among the studied populations and ethnic groups, the highest values for NLA were reported in the Saudi population[17]102.85±10.68 degrees in males and 109.68±11.4degrees in females;Turkish population[19], 105.7±9.5 degrees in male subjects and 108.4±8.4 degrees infemale subjects; Yemeni (reported by Celebi, 2013)[19] with a mean of 107.6±7.9 degrees. The lowest values were reported in the Black American population with 76.27±18.01 degrees in men and 77.05±15.25 degrees in women, which indicates no significant difference between sexes, although it has a broad range. A lower acute angle was also reported in the Japanese population[29]with values of 90.7±10.4 degrees in men and 92.2±8.7 degrees in women, similar to the value in Korean women reported by Choi[27], 90.36±8.1 degrees. The lower values of the nasolabial angle might be attributed to bimaxillary protrusion in the Black American population or the

difference in lip thickness. The mean and standard deviation (SD) calculated by Arnett and Bergman in the Caucasian population were 103.5±6.8 degrees. The wide range of NLA values might be attributed to interpopulation differences and are accepted as the normal values for the respective populations.

Upper Lip Length (ULL) measurement is used in Arnett-Bergman, Burstone, and Epker analyses with the mean reported by Arnett being 21±1.9 mm[4]. The highest values of the ULL were reported in the Korean population[28]with 29.2±2.1 mm in men and 28.3±1.9 in women, and the Black American population[30] with 27.72±2.46 mm in men and 26.34±2.89 mm in women. The lowest values were reported in the South Indian population by Arora[23]with 19.96±1.89 and 17.81±1.94 mm, for males and females, respectively, and in theMahbubnagar population[25] with 17.83±1.72 mm in males and 16.93±1.96 mm in females.

The upper lip length is closely related to the upper incisor exposure measurement implemented by Arnett-Bergman, Burstone, and Legan. Arnett suggested 4.7±1.6mm as a reference. Although Korean women[27]were reported to have shorter upper lip length compared to that in European-Caucasians, the upper incisor exposure in this group was 2.73±1.17 mm, which is lower than that suggested by Arnett[4]. Upper incisor exposure in the Saudi population was comparable to that in the Caucasian population; 3.18±2.48 mm in men and 3.37±1.38 in women[17]. The lowest values were found in the Mala-Chinese population, averaging 0.16±0.78 mm[35].

The lower lip length, as measured by Arnett, Burstone, and Epker analyses, includes both lower lip and chin length and has a value of 46.9±2.3 mm. Among the studied populations and ethnic groups, the highest values were found in Saudi men (50.4±3.9 mm) [16],Black American men (50.94±3.6mm), and Black American women (49.52±3.89mm)[30]. The lowest measurements were found in the Mahabubnagar population with 39.87±2.89mm in male subjects and 37.6±1.91 mm in female subjects. As reported by Burstone[8,] the ratio of the upper lip length to the lower lip-chin length in the normal face is 2:1 in favor of the lower lip-chin dimension. In the Mahabubnagar population, the ratio of the upper lip to the lower lip-chin length is 2.23:1 in favor of the latter, while in the Black American population, that ratio is 1.84:1 in favor of the lower lip-chin dimension. The smaller ratio is caused by the increased upper lip length in the Black American population.

The interlabial gap was measured as 3.3±1.3 mm by Arnett and Bergman. The value reported by Arnett is, on average, higher than those reported in different populations, except for the Saudi population[17] where it is 2.69±1.24 mm for males. The lowest values are reported in Malaysian Indian[35] (0.19±1 mm) and Malaysian Chinese (0.19±0.56 mm) populations. The broadest range was found in Korean females with a mean of 1.52±6.03 mm[27]

The upper lip thickness was expected to be related to the nasolabial angle, with higher values contributing to acute angles. When measured based on the Arnett-Bergman analysis, the upper lip thickness value had a mean value in the Caucasian population of 12.6±1.8 mm. The highest values were found in Nigerian males with a mean value of 15.06±1.67 mm[31]. The lowest values were found in the South Indian population (10.7±1.04 mm)[23]and Mahabubnagar female subjects (9.68±1.01 mm)[25].

In Holdaway analysis, upper lip thickness was measured as basic upper lip thickness and upper lip strain. Both measurements were highest in Persian men (18.09±2.21mm and 15.59±2.9 mm, respectively)[20] and Iranian men (16.93±2.67 mm and 14.77±2.65 mm, respectively). The lowest values of basic upper lip thickness were reported in Malay women[38](12.68±-0.63 mm), while the lip strain measurement was higher in this population(14.00±1.92 mm).

Position of the upper and lower lips relative to the E-plane, as defined by Ricketts, was retrusive in the European American population[29] with values of -6.4±2.4 mm in men and -5.7±2.9 in women for the upper lip, and -4.3±2.4 mm in men and -3.2±2 mm in women for the lower lip. Similarly, comparable values were reported in the Anatolian Turkish population (upper lip in men, -4.97±2.55 mm; upper lip in women, -5.03±2.09 mm; lower lip in men, -2.7±2.27 mm; lower lip in women, -2.19±2.48 mm)[18],and in the Iranian population[21] (upper lip in men, -5.04±2.03 mm; upper lip in women, -5.01±2.17 mm; lower lip in men, -2.19±2.48 mm; and lower lip in women, -2.28±2.48 mm). The highest values were found in the Nigerian population in subjects (both men and women) with pleasing profiles[31],the upper lip position relative to the E-plane in men was reported as 4.07±2.66 mmand 2.54±2.54 mm in women. The lower lip position was found to be even more protrusive with a value of 7.88±2.7 mm in male subjects and 5.88±2.64 in female subjects. The range of acceptable lip positions in different populations suggests the existence of population/ethnic group-specific norms. Thus, the measurements found prevalent in one population might not be applicable to a different population. Moreover, any measurements that do not lie within the range of the original norms suggested by the author of the respective cephalometric analysis should be interpreted with caution.

Conclusion

Based on the available data, the following conclusions could be drawn:

1. Ricketts' analysis of lip position is the most widely used, followed by the Arnett-Bergman analysis.

2. The reported soft-tissue cephalometric measurements among the 17 populations/ethnic groups are highly variable and differ from those reported in Caucasian populations.

3. The soft tissue cephalometric lip measurements listed in this systematic review could serve as reference standards for their respective populations/ethnic groups.

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Appendix. PubMedSearchHistory

Search number	Query	Results
22	((((((((((population group[MeSH Terms]) OR (adult[MeSH Terms])) OR (males[MeSH Terms])) OR (females[MeSH Terms])) OR (orthognathic surgery[MeSH Terms])) OR (orthognathic surgical procedures[MeSH Terms])) OR (Botulinum toxin[MeSH Terms])) OR (hyaluronic acid[MeSH Terms])) OR (orthodontics[MeSH Terms])) OR (prosthodontics[MeSH Terms])) AND ((cephalometry[MeSH Terms]) OR (dental radiography[MeSH Terms]))) AND ((((((face[MeSH Terms]) OR (mouth[MeSH Terms])) OR (lip[MeSH Terms])) OR (cleft lip[MeSH Terms])) OR (reference standards[MeSH Terms])) OR (reference values[MeSH Terms]))	12005
21	(((((face[MeSH Terms]) OR (mouth[MeSH Terms])) OR (lip[MeSH Terms])) OR (cleft lip[MeSH Terms])) OR (reference standards[MeSH Terms])) OR (reference values[MeSH Terms])	628545
20	reference values[MeSH Terms]	160576
19	reference standards[MeSH Terms]	44875
18	cleft lip[MeSH Terms]	15276
17	lip[MeSH Terms]	11768
16	mouth[MeSH Terms]	296488
15	face[MeSH Terms]	159864
14	(cephalometry[MeSH Terms]) OR (dental radiography[MeSH Terms])	47696

13	dental radiography[MeSH Terms]	22137
12	cephalometry[MeSH Terms]	26935
11	(((((((((population group[MeSH Terms]) OR (adult[MeSH Terms])) OR (males[MeSH Terms])) OR (females[MeSH Terms])) OR (orthognathic surgery[MeSH Terms])) OR (orthognathic surgical procedures[MeSH Terms])) OR (Botulinum toxin[MeSH Terms])) OR (hyaluronic acid[MeSH Terms])) OR (orthodontics[MeSH Terms])) OR (prosthodontics[MeSH Terms])	7614948
10	prosthodontics[MeSH Terms]	118418
9	orthodontics[MeSH Terms]	52672
8	hyaluronic acid[MeSH Terms]	21815
7	Botulinum toxin[MeSH Terms]	16346
6	orthognathic surgical procedures[MeSH Terms]	5783
5	orthognathic surgery[MeSH Terms]	6081
4	females[MeSH Terms]	37102
3	males[MeSH Terms]	4688
2	adult[MeSH Terms]	7302990
1	population group[MeSH Terms]	302985