Journal of
Physiotherapy & Physical Rehabilitation

Haas et al., Physiother Rehabil 2016, 1:2
DOI: 10.4172/2573-0312.1000110

Research Article Open Access

Which Reference Line Describes Head Position Best?

Anne-Louise Haas*, Katrin Bracht, Thomas Stöggl and Reinald Brunner

University Children's Hospital Basel, Laboratory of Movement Analysis, Switzerland

Abstract

Background and Purpose: It is generally assumed that the head is positioned on the body plumb line. The reference line defined by Kendall (KL) (1952, Kendall et al. 2005) is the most citied one. We hypothesized that the head is held anteriorly to the KL and the gravity line (GL) derived from the center of mass (CoM). The purpose of the study was to objectively assess the relation between head position and GL / KL in the sagittal plane using a 3d-tool to define the CoM.

Methods: Head center (HC) and CoM were calculated in 30 normal subjects (25-35 years) while standing using a three dimensional motion analysis system. The distance from the GL (defined by the CoM) and KL (two cm in front of the lateral malleolus) to the HC was calculated.

Results: All 30 subjects held their HC anterior to the KL. The HC was anterior to the GL in 11 subjects, through the GL in four and posterior to the GL in 15.

Conclusion: According to this study the two references lines cannot be considered the same, suggesting that previous assumptions about this relationship may be inaccurate. KL was not discriminative in our subjects for HC position.

Keywords: Head position; Normal posture; Gravity line; Body plumb line; Reference line

Introduction

It is commonly accepted that the head is held aligned with the body plumb line. This line corresponds to the gravity line (GL) which passes through the body's center of mass (CoM) [1,2]. However, this does not accord with our clinical impression where the head seems to be positioned anterior to the GL. There is no uniform definition of head position and head posture. Braun and Amundson described the forward head position FHP as the relationship of the head to the GL which travels through the CoM [3]. Moorees defined the natural head posture with an upright posture and the eyes directed horizontally in respect of the Sella-nasion line [4]. Cole compared two different terms, the 'natural head position' (the distance from a line through the nasion and the sella in respect of vertical line in front of the head) and the 'natural head posture' (the distance from the line through the nasion and the sella to the spine on x-rays). He found a significant difference for these two terms in normal individuals [5]. Shaghayegh et al. measureded the craniovertebral angle between a FHP and a healthy group in sitting and standing position and described a significant difference [6]. Kendall H. defined normal posture based on data from elite soldiers. He found the apex of the coronal suture, the auditory meatus and the dens axis perpendicularly aligned and in alignment to the plumb line [7]. In 2005 Kendall F. used the same approach and related various head postures in standing to a plumb line through a fixed point which she defined to be "sl ant. [slightly anterior] to the ankle joint thru the calcaneocuboid joint" [8]. It was assumed that this plumb line according to Kendall (KL) [8] coincided with the GL, but the CoM as the basis for GL [9] was not determined. GL, however, passes through the CoM and is not defined in respect of the foot. Gender differences in head position have been noted by Hanten et al who measured the distance from the head to the wall with a ruler in standing healthy subjects and found that males had their head more anterior compared to females [10].

There is some confusion on the reference line for the assessment of head position which influences the FHD. A standardized definition is therefore desirable. Most studies assessing head position used photography and assumed that the plumb line drawn on the photograph was the gravity line. Photography has a major limitation as it does not take into account body sway and corresponding movements of the CoM.

Cromwell et al. used sagittal video analysis to determine how the neck and head are stabilized during gait but not standing [11]. Three dimensional methods to determine CoM and head position have not been carried out previously. The lack of accurately determining the head center (HC) and CoM further increases the difficulty to accurately assess head position.

Aims and Hypothesis

This study aims to define the relationships between the KL and GL (defined by the CoM) in respect of the HC using three dimensional kinematic analyses in normal individuals while standing in order to define head position in the sagittal plane. We are not aware of these methods having been used previously in this type of study.

We hypothesized that the head is held anterior to the KL and the GL.

Methods

Study design and population

Thirty healthy and normal subjects (13 m, 17 f, age 25-35 years) were included for this pilot study (Table 1) which compared two reference lines in respect of discriminating the head position. As one

***Corresponding author:** Anne-Louise Haas, Physiotherapist, University Children's Hospital Basel, Laboratory of Movement Analysis, Spitalstrasse 33, Basel, 4056, Switzerland, Tel: 0041764026426; E-mail: alu.haas@sunrise.ch

Received: April 28, 2016; **Accepted:** May 13, 2016; **Published:** May 20, 2016

Citation: Haas AL, Bracht K, Stöggl T, Brunner R (2016) Which Reference Line Describes Head Position Best? Physiother Rehabil 1: 110. doi: 10.4172/2573-0312.1000110

line turned out to be not discriminative we renounced to calculate statistical significances. The subjects were recruited by a call on the web site of the Basel University. This age group was chosen as they have not developed cervical degenerative [12-14]. Any known structural pathology, such as spinal deformity, malformation, spinal disease or a past history of cervical trauma was exclusion criteria.

There is no consistent definition for a reference line to describe head position. As many authors use Kendall's 1952 definition to describe normal posture and head position, we used the KL [7,8] and GL [9] as reference lines for our study.

Ethical considerations

A cohort study was carried out with approval from the local ethical committee and informed, written consent from subjects.

Procedure

A marker-based movement analysis system (VICON 460, 12 cameras, at a sampling rate of 120 Hz, Oxford Metrics, Oxford, UK) was used to define the head position in normal subjects while standing. The same technique is a standard for gait analysis [15,16]. Passive reflective markers (14 mm) were attached on the skin at bony landmarks (15 markers at the lower extremities according to Kadaba et al. [17] and 19 markers were attached to the trunk, the arms and the head (the four head markers are mounted on a headband) according to Gutierrez et al. [18] (Figure 1). The infrared video system (8 cameras) followed the markers in a calibrated 3D-space. This data (marker co-ordinates) was imported into the Nexus software (VICON Body Builder, Nexus with Plug in Gait 2012, and Polygon software, Oxford Metrics, Oxford, UK) which used the data to construct an individual skeletal model at any moment in time. For this purpose a deposited skeletal model was scaled according to the individual anthropometric data (limb length, body height, body weight) including the distribution of segmental masses. The total body CoM estimate was the weighted sum of the CoM position of the individual segments [19].

We asked the subjects to stand with their weight equally on both legs and read a line from an eye chart positioned on a wall at eye level four times; this was to control the head direction of the subjects. Between each of the four assessments subjects walked a few steps to obtain four independent measurements. As the software program set up for motion analysis requires a time period (as a correlate for a gait cycle) for data calculation a period of 20 sec was chosen from the static trial of the present study. The analysis was restricted to the sagittal plane where the co-ordinates in the horizontal direction (y-axis of the lab) were used to calculate the distance and direction of the head center position and the GL. The GL was given by the y co-ordinate (sagittal plane) of the CoM from the Plug in Gait model. The head center (HC) was defined as the geometrical mean of the y-co-ordinates (sagittal plane) of all four head markers. Kendall et al defined their reference line as a line passing through several body landmarks which all are positioned on the plumb line. For this reason geometrically one landmark can be used as a substitute for all others in combination with the plumb line. We interpreted the rather vague definition of KL ("slightly anterior to the lateral malleolus through calcaneocuboid joint" [8]) as about two cm anterior to the lateral malleolus which is about the distance between the lateral malleolus and the calcaneocuboid joint in normal adults.

The distance of the HC to the respective reference line GL or KL in the sagittal plane was calculated in mm as the difference of the y-co-ordinates. The mean of the four trials was taken for further analysis (Figure 2).

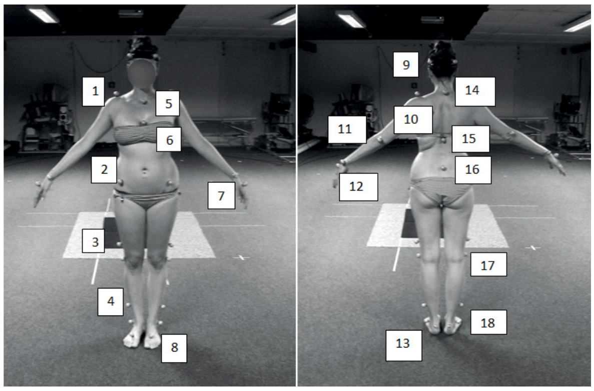

Figure 1: Marker position. Marker placement (SIAS=superior anterior iliac spine; SIPS=superior posterior iliac spine). 1=acromion, 2=SIAS, 3=on line connecting the greater trochanter with the lateral condyle, 4= on line connecting lateral epicondyle and lateral malleolus, 5 = sternum, 6=xiphoid process, 7=2nd metacarpal bone, 8=2nd metatarsal bone, 9=4 head, 10=left scapula, 11=Lateral condyles, 12 =ulnar and radial styloids, 13=tuber calcanei, 14=C 7, 15=TH 10, 16=inter SIPS, 17= lateral epicondyle, 18=lateral malleolus.

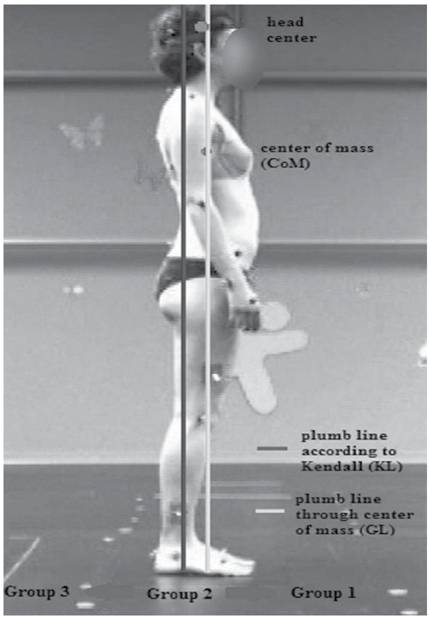

Figure 2: The two reference lines (schematic): gravity line (GL) with his three groups and plumb line according to Kendall (KL). Head center = HC; center of mass = CoM; gravity line through the center of mass (GL) according to group 1 (HC anterior the GL), group 2 (HC centered) and group 3 (HC posterior the GL); plumb line according to Kendall (KL).

Statistical analysis

The head position with respect to KL and GL was descriptively analyzed and presented as mean across the four trials per subject ± standard deviation.

Results

All subjects held their HC in front of the KL (mean 107 ± 27 mm) which made a grouping based on the KL impossible (Table 2 and Figure 3).

The mean distance between HC to GL and HC to KL was 114 ± 18 mm.

The subjects were subdivided into groups using the relationship of the head center with respect to the gravity line. In Group 1 HC was anterior to the GL, in Group 2 the HC was centered over the GL and in Group 3 the HC was posterior to the GL. According to Yang et al. the overall margin of the error of marker displacement recording for the VICON system was calculated to be 3.6 mm (0.3 mm in the lab axes x and y *6 markers=3.6 mm) [20]. The range for Group 2 was set accordingly (± 3.6 mm from GL), whereas >3.6 mm was Group 1 and <-3.6 mm was Group 3 (Figure 2).

The analysis between the HC and GL showed three head positions: Group 1 comprised 11 subjects, Group 2 four subjects and Group 3 15 subjects (Figure 3). The mean distance for the whole cohort was 7 ± 19 mm (Tables 1 and 2).

Discussion

Our hypothesis that the HC was anterior to the KL was confirmed in all thirty normal subjects but there were three different patterns for the relationship of the HC to the GL. Only four out of 30 individuals held their HC in the GL, which is in agreement with the general clinical assumption. Eleven had the HC anterior and 15 posterior to the GL. Our hypothesis that the head is always held in front of the GL was therefore not supported. We found a difference between the HC depending on which reference line, KL or GL, was used of 11.37 cm on average. We conclude that the two reference lines KL and GL do not correspond with each [8].

The three dimensional analysis applied in this study had the advantage of calculating the CoM of the body more accurately from anthropometric data. In the present study, two reference lines, GL through this CoM and KL, were calculated in contrast to earlier studies for comparison. They were, however, contradictory. Especially the lack of discriminative power of the KL casted doubt on its utility. Three dimensional analysis of head posture and its relationship to the GL, derived from the CoM, seemed to offer a better option for a reference line in future studies. Normal data on head alignment using three dimensional analysis would be required to test this option in a larger population. A further improvement of accuracy would be the calculation of the CoM of the head and not deriving it from a geometrical midpoint. The conventional definition of a normal head posture should also be reconsidered.

	Total cohort	Group 1	Group 2	Group 3
Total	30	11	4	15
Females	17	6	2	9
Males	13	5	2	6
Mean age ± SD (range)	28.4 ± 3.0 (25-30)	27.3 ± 1.7 (25-30)	30.3 ± 2.6 (28 – 34)	28.7 ± 3.5 (25-34)
Mean distance HC-GL ± SD; **Min / Max**	-7.8 mm ± 18.6 mm; -43.0 mm/ 21.5 mm	12.4 mm ± 5.6 mm; 4.6 mm / 21.5 mm	-0.8 mm ± 0.9 mm; -1.7 mm / 0.1 mm	-22.9 mm ± 10.9 mm; -43.0 mm/-3.5 mm
Mean distance HC-KL ± SD; **Min / Max**	106.7 mm ± 26.9 mm; 37.4 mm/156.0 mm	123.1 mm ± 18.2 mm; 101.5 mm/154.0 mm	123.4 mm ± 23.0 mm; 106.1 mm/156.0 mm	90.2 mm ± 23.7 mm; 37.4 mm/121.0 mm

Table 1: Distribution of age, sex, distance head center (HC) to gravity plumb line GL in the total cohort, group 1 (HC anterior to GL), group 2 (HC centered) and group 3 (HC posterior to GL) and distance HC to plumb line according to Kendall (KL). SD = Standard deviation, HC = Head center, GL = Gravity line through the center of mass, KL = Plumb line according to Kendall.

	HC-GL	HC-KL
1	-15.4 mm	104.9 mm
2	-1.4 mm	108.4 mm
3	-13.2 mm	89.5 mm
4	4.6 mm	101.5 mm
5	12.8 mm	101.8 mm
6	5.1 mm	115.3 mm
7	-24.9 mm	60.7 mm
8	-43.0 mm	37.4 mm
9	7.3 mm	144.4 mm
10	21.4 mm	126.4 mm
11	12.2 mm	106.0 mm
12	-1.7 mm	106.1 mm
13	13.5 mm	120.3 mm
14	-0.2 mm	123.0 mm
15	-37.2 mm	68.2 mm
16	21.5 mm	154.0 mm
17	-35.8 mm	64.6 mm
18	10.4 mm	131.7 mm
19	-3.5 mm	102.3 mm
20	14.0 mm	142.8 mm
21	-18.0 mm	108.5 mm
22	-21.9 mm	112.3 mm
23	13.2 mm	110.4 mm
24	-19.3 mm	77.9 mm
25	-16.4 mm	110.4 mm
26	-11.4 mm	98.6 mm
27	-21.6 mm	121.0 mm
28	-33.4 mm	89.9 mm
29	0.1 mm	156.0 mm
30	-27.6 mm	107.1 mm

Table 2: Distance HC-GL and distance HC-KL of each participant. HC=Head center, GL=Gravity line through the center of mass, KL=Plumb line according to Kendall.

It is generally accepted that a FHP may require additional cervical paraspinal muscle activity to maintain posture [21]. In their textbook Kendall et al. described the untested observation that incorrect head-neck alignment may cause neck pain [8]. Several studies noted a FHP in healthy subjects and in patients with neck pain [22-25]. They do not, however, refer to a common reference line which may lead to different results. The assessment of the head position thus is relevant for patients with neck pain, and a reliable and discriminative reference is wanted. Defining a line through the CoM may be an option. This study has several limitations: One is the calculation of the CoM based on an individually scaled anthropometric model (Plug in Gait). As a normal individual is used for the basic model which is scaled and during motion defined by the trunk and pelvis markers, certain shapes like a large belly is not represented and thus CoM in such cases will not be accurate. However, the individuals were young and normal without any obvious aberration from average. Despite these limitations the VICON system is widely accepted as a standard investigative tool that compares well with other methods of measuring kinematic and kinetic data [26-28]. The KL was calculated as a line 2 cm in front of the marker on the lateral malleolus. This is the usual distance to the calcaneocuboidal joint. For an exact positioning x-rays would have been required which is ethically not acceptable. This calculation introduces an error as the distance depends from the individual anatomy (such as foot size). As

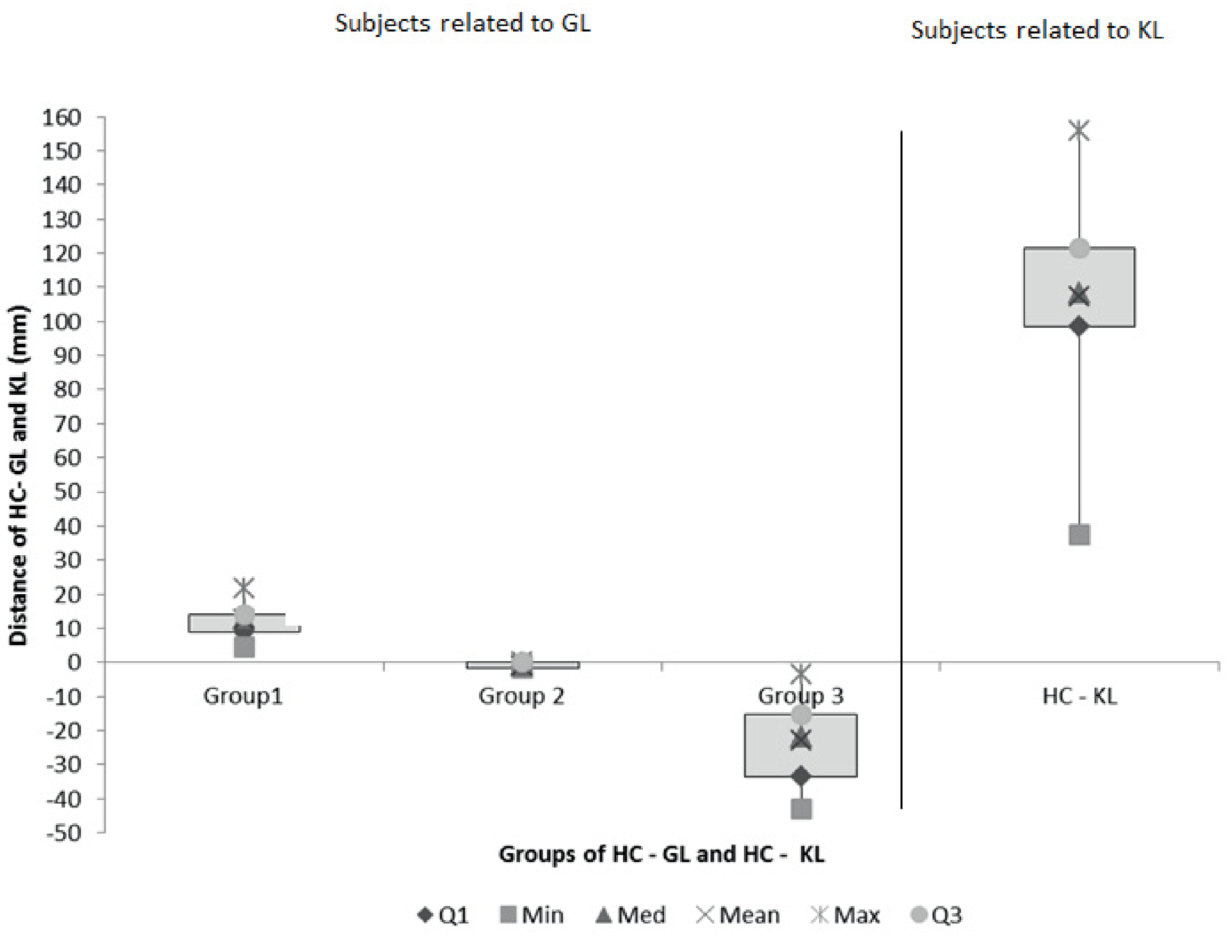

Figure 3: Distance of the head center to the gravity line GL according to the groups and plumb line according to Kendall KL. The mean distance of the head center (HC) to the gravity line through the center of mass (GL) according to group 1 (HC anterior the GL), group 2 (HC centered) and group 3 (HC posterior the GL;) and the plumb line according to Kendall (KL) of all 30 subjects is plotted in mm. Min=Minimum, Q1=first quartile (25 %), Med =Median (50%), Mean, Q3=third quartile (75%), Max=Maximum.

the differences between KL and GL were about one cm or more we do not expect a major influence on the message of the study. The small number of 30 subjects is also a limitation but does suggest that a new reference line should be considered for the relationship of head posture in a larger population. If this study were to be repeated it would be preferable to adjust the level of the eye chart individually to minimize adaptive head movements. For clinical purposes this three dimensional approach may be too elaborate but does highlight the shortcomings of the KL method. A simpler method to calculate CoM is desirable in the future.

Conclusion

The most frequently cited reference line KL does not align with the plumb line through the center of mass.

Conflict of Interest Statement

The authors have not conflicts of interest to declare.

References

1. Perry J (1992) Gait analysis- normal and pathological function. In Slack Incorporated, New York.
2. von Strebel A (2001) Die Wirbelsäule. In Georg Thieme Verlag, Stuttgart.
3. Braun BL, Amundson LR (1989) Quantitative assessment of head and shoulder posture. Arch Phys Med Rehabil 70: 322-329.
4. Moorrees C F (1994) Natural head position-a revival. Am J Orthod Dentofacial Orthop 105: 512-513.
5. Cole SC (1988) Natural head position, posture, and prognathism: the Chapman Prize Essay,1986. Br J Orthod 15: 227-239.
6. Shaghayegh FB, Ahmadi A, Maroufi N, Sarrafzadeh J (2015) Evaluation of forward head posture in sitting and standing positions. Eur Spine J.
7. Kendall H (1952) Posture and Pain. In: Williams, Wilkins (eds.) Baltimore.
8. Kendall F, Kendall E, Provance P, Rodgers M, Romani W (2005) Muscles-Testing and function with posture and pain. (5th edn). Lippincott Williams & Wilkins. Baltimore.
9. Hüter-Becker A, Dölken M (2005) Biomechanik, Bewegungslehre, Leistungsphysiologie, Trainingslehre. Georg Thieme Verlag. Stuttgart.
10. Hanten WP, Lucio RM, Russell JL, Brunt D (1991) Assessment of total head excursion and resting head posture. Arch Phys Med Rehabil 72: 877-880.
11. Cromwell RL, Aadland-Monahan TK, Nelson AT, Stern-Sylvestre SM, Seder B (2001) Sagittal plane analysis of head, neck, and trunk kinematics and electromyographic activity during locomotion. J Orthop Sports Phys Ther 31: 255-262.

12. Jensen MC, Brant-Zawadzki N (1994) Magnetic resonance imaging of the lumbar spine in people without back pain. N Engl J Med 331: 69-73.
13. Matsumoto M, Fujimura Y (1998) MRI of cervical intervertebral discs in asymptomatic subjects. J Bone Joint Surg Br 80: 19-24.
14. Weishaupt D, Zanetti M (1998) MR imaging of the lumbar spine: prevalence of intervertebral disk extrusion and sequestration, nerve root compression, end plate abnormalities, and osteoarthritis of the facet joints in asymptomatic volunteers. Radiology 209: 661-666.
15. Perry J, Burnfield JM (2010) Gait analysis : normal and pathological function. J Sports Sci Med 9: 353.
16. Rose J, Gamble JG (2006) Human walking. Lippincott Williams & Wilkins. Philadelphia.
17. Kadaba MP, Ramakrishnan HK, Wootten ME (1990) Measurement of lower extremity kinematics during level walking. J Orthop Res 8: 383-392.
18. Gutierrez EM, Bartonek A, Haglund-Akerlind Y, Saraste H (2003) Centre of mass motion during gait in persons with myelomeningocele. Gait Posture 18: 37-46.
19. González A, Hayashibe M (2014) Whole Body Center of Mass Estimation with Portable Sensors: Using the Statically Equivalent Serial Chain and a Kinect. Sensors 14: 16955-16971.
20. Yang PF, Sanno M, Brüggemann GP, Rittweger J (2012) Evaluation of the performance of a motion capture system for small displacement recording and a discussion for its application potential in bone deformation *in vivo* measurements. Proc Inst Mech Eng H 226: 838-847.
21. Knight JF, Baber C (2004) Neck muscle activity and perceived pain and discomfort due to variations of head load and posture. Aviat Space Environ Med. 75: 123-131.
22. Ayub E, Glasheen-Way M, Kraus S (1984) Head posture: a case study of the effects on the rest position of the mandible. J Orthop Sports Phys Ther 5: 179-183.
23. Mohl ND (1976) Head posture and its role in occlusion. N Y State Dent J 42: 17-23.
24. Passero PL, Wyman BS, Bell JW, Hirschey SA, Schlosser WS (1985) Temporomandibular Joint Dysfunction Syndrome : A Clinical Report. Journal of the american physical therapy association 65: 1203-1207.
25. Rocabado M (1983) Biomechanical relationship of the cranial, cervical, and hyoid regions. J Craniomandibular Pract 1.3: 61-66.
26. Eames MH, Cosgrove A, Baker R (1999) Comparing methods of estimating the total body centre of mass in three-dimensions in normal and pathological gaits. Human Movement Science 18: 637-646.
27. Gutierrez-Farewik EM, Bartonek A, Saraste H (2006) Comparison and evaluation of two common methods to measure center of mass displacement in three dimensions during gait. Hum Mov Sci 25: 238-256.
28. Lee HK, Cho SP, You JH, Lee KJ (2007) The concurrent validity of the body center of mass in accelerometric measurement. Conf Proc IEEE Eng Med Biol Soc 2007: 659-661.

Citation: Haas AL, Bracht K, Stöggl T, Brunner R (2016) Which Reference Line Describes Head Position Best? Physiother Rehabil 1: 110. doi: 10.4172/2573-0312.1000110