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Temporal Stability and Reliability of an Adaptation of the Linear Excursion Measurement Device

Umunnah Joseph Onuwa[1*], Nwaefulu Violet Akuakananwa[1], Ihegihu Yvonne Ebere[2] and Okeke Chukwuebuka[2]

[1]Department of Medical Rehabilitation, Nnamdi Azikiwe University, Nnewi Campus, Nnewi, Anambra State, Nigeria

[2]Department of Physiotherapy, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria

[*]**Corresponding author**: Umunnah, Joseph Onuwa, Department of Medical Rehabilitation, Nnamdi Azikiwe University, Nnewi Campus, Nnewi, Anambra State, Nigeria, Tel: 401-261-5236; E-mail: jo.umunna@unizik.edu.ng

Abstract

Background: The Linear Excursion Measurement Device (LEMD) is used to detect and objectively record changes in cervical posture over time and in quantifying the effectiveness of physiotherapy interventions for posture-related problems.

Objective: The study investigated the temporal stability and reliability of measurements obtained from the LEMD; and the influence of time of day on the measurements obtained.

Methods: The study involved 46 volunteering apparently healthy undergraduates (mean age 22.3 ± 2.26years). Vertical and horizontal movements at the selected landmarks were obtained from the LEMD (morning and afternoon) for four consecutive days, and the excursion angles computed for each day. Data obtained was presented using descriptive statistics of mean and standard deviation, and analyzed using inferential statistics of Paired t-test and Pearson Product Moment Correlation Coefficient. Level of significance was set at <0.05.

Results: Average total time of measurement per participant for the 4 days was 145 seconds. No significant difference was found between morning and afternoon values for computed excursion angles at both landmarks; and in the average daily computed excursion angles within the 4 days (p>0.05 in each case). A significant correlation existed between day 1 and 2 (r=0.247, r=0.316), day 1 and 3 (r=0.425, r=0.478), and day 1 and 4 (r=0.274, r=0.592) at both landmarks respectively.

Conclusions: LEMD is time efficient and reliable with temporal stability. It can be used by physiotherapists for assessing and quantifying improvement in patients with cervical spine problems.

Introduction

Postural distortions arising from cervical spine problems are fairly common in a typical physiotherapy clinic. Assessment of these postural distortions may give a good idea of either the causative factors or the possible complications of cervical problems; and may give an insight into possible outcomes of intervention. The search for reliable methods for assessing human posture has stimulated various studies, which have produced both subjective and objective methods of measuring range of cervical resting posture [1] most of which have been limited to mainly research settings and have found little application in the clinics. Methods such as photography using projected protractors quantifies the resting angle of the skull on the base of neck by measuring angle of the tragus to C7 line from the horizontal [1]. Grimmer [1] however observed that it does not determine the amount of sagittal excursion which occurs during assumption of head resting position; and may not be as appropriate in assessing day-to-day changes in cervical posture as the total head excursion concept of Hanten et al. [2]. Given the philosophy of postural correction which underlies the physiotherapy management of

such posture-related disorders, [3-5] there is need to measure the forward movement of the head relative to a fixed point [1].

The cervical spine curve is convex forward (lordotic), extending from the first cervical (C1) to the second thoracic (T2) vertebra with its motion considered to involve the upper (i.e. atlanto-occipital and atlanto-axial complexes) and the lower cervical spine level (C3-C7). The movements permitted at the atlanto-occipital joint are flexion-extension and lateral flexion, while flexion-extension and rotation occur at the atlanto-axial joint [6,7]. Although, it has been demonstrated that there is a wide variation in individual spinal joint movement, the degree of upper and lower cervical excursion occurring in the sagittal plane as subject moves into their usual resting posture from a corrected posture [2] is an area that has received little mention. Furthermore, determining the linear movements of at least two body landmarks will enhance the measurements of upper and lower sagittal cervical excursion angles [1].

Despite technological advances in measurement techniques, there is still much need to learn about cervical posture in terms of understanding how the neck balances the head against the force of gravity. The individual spinal segments of the neck assume different relative positions depending on the individual's genetic, anatomical construction, occupational demands, muscle strength and endurance,

as well as mental state, personality and culture; and valid measures which can capture this objectively and reliably continue to challenge clinicians and researchers [8].

The linear excursion measurement device (LEMD) was developed in a treatment setting as a means of providing serial measurement of sagittal excursion from a corrected position of maximum retraction of the chin to the usual resting head position, and the development was stimulated by the non-availability of a reliable but inexpensive means of measuring changes in cervical posture in a clinical setting. [1]. Given an assurance of consistent measurements, the LEMD may offer a means of detecting and objectively recording changes in cervical posture over time; which will assist in describing the range of head posture found in the population, and in quantifying the effectiveness of physiotherapy intervention for posture related problems. The LEMD was designed as a low cost, portable and reliable means of measuring the horizontal and vertical movements traced by the two anatomical reference points during excursion movement of the head from the standardised cervical resting position to its habitual resting position; thus, adding a vertical dimension to Hanten et al. [6] methodology of horizontal excursion. Previous study by Grimmer [1] suggested that the LEMD must be exposed to rigid scrutiny before it becomes universally accepted as an outcome measure for physiotherapists.

The concept of using LEMD has been sparsely recorded in the literature [1], and thus must be exposed to rigid scrutiny before it becomes universally accepted as an outcome measure for the physiotherapist with such scrutiny including testing on a large sample size for inter-examiner reliability, assessing subjects with cervical pain and/or dysfunction with the device, and also to compare measurements from the device with other postural devices with a view of finding the best outcome measurement device to be adopted. We observed in our clinical experiences so far, that there is no inexpensive, time efficient, easily accessible, and reliable quantitative objective evidence of the success of physiotherapy intervention in management of cervical posture and/or dysfunction or other posture-related problems given the financial pressures on health systems; and have yet to come across any study that rigidly scrutinized the LEMD in order to establish its suitability for this environment.

The general aim of this study was to scrutinize the temporal stability and reliability of the computed cervical excursion angles obtained from LEMD amongst a sample of persons living in south-eastern region of Nigeria, and to investigate the influence of time of day on the computed excursion angles obtained from the LEMD with a view of advocating its use as an objective evidence-based measure of intervention in management of cervical postural dysfunction or other posture-related problems.

Materials and Methods

The study adopted an ex-post facto research design. Apparently healthy undergraduates of a Nigerian university comprising 27 males and 19 females, who volunteered, were randomly selected. Participants were excluded on the basis of previous injury to the neck or back, past surgery done to the neck or back, posture related disorder, pregnant or lactating due to altered hormonal activity, current use of analgesics, muscle relaxants, or anti-inflammatory drugs. Ethical approval was sought and obtained from the Ethical Review Committee of the Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria before commencing the study.

Measurements were obtained using an adapted Linear Excursion Measurement Device (LEMD) and the procedure as described by Grimmer [1]. The procedures were explained to the participants, and their informed consents were obtained. Participant's bio-data which include gender, age and height were obtained and recorded. The researchers spent a period of two weeks training on the use of the research instruments and procedures.

Research instruments

Construction of adapted LEMD: Was used to measure the sagittal cervical excursion from a corrected chin retraction to the usual resting head position. The LEMD consist of a vertical backboard attached at right angles to a horizontal board seat. Two vertical slots were cut, one onto the centre of the backboard, and one 15cm to the right of the centre slot. A frame, fitted parallel to each slot on the rear of the backboard accommodated a sliding bracket. A casing, mounted on to the sliding bracket allowed a T-square calibrated in centimetre to run through the vertical slot. Each casing had two screws: one to control the horizontal movement, and the other to control the vertical movement of the calibrated T-square within the casing. A centimetre ruler pointer was aligned parallel to each vertical slot on the rear of the backboard [1]. A jack was fixed to the horizontal seat board which served as the adjustable stool allowing the participants to sit with hip, knee, and ankle at 90°, thus standardizing the erect posture of the spine so as to avoid trick movement by the other spinal region on the cervical region.

Height meter: Was used to determine the height of the participants.

Stop watch: Was used to measure the time taken to carry out the measurement and record the result.

Indelible marker: Was used to mark the two selected anatomical reference points.

Wall chart: Was used to fix the eye level horizontally so as to keep the head erect and standardized.

Procedure for Data Collection

Ethical approval was sought and obtained from the institutional review committee of the Nnamdi Azikiwe University Teaching Hospital, Nnewi, before commencement of the study. The procedures were explained to the participants, and their informed consents obtained. The participants were screened in line with the inclusion criteria. The measurement procedures as well as derivation formulae for variables are as follows:

Two anatomical reference points i.e. superior-most tip of the helix of the ear as an indicator of skull movement (because it is clearly visible, moves in direct relation to the skull and can be indelibly marked for re-measurement) was marked as the first point and the spinous process of C7 (because it can be located by sight and palpation when the person's neck is flexed as far as possible] as the second point [1].

As each participant sat on the LEMD, the hips, knees, and ankles joints were kept in 900 by pumping the jack. After this, the time keeper started the stop watch and participants were asked to comfortably rest the forearms on their thighs while the selected reference points were marked. They were then instructed to maximally retract their chins by pressing the back of their head and their shoulder blades onto the vertical backboard (so as to standardize the chin retraction mobility) and this was the starting position for all the measurements [1].

Participants were then asked to spot a letter level with their horizontal gaze on a wall chart in front of them. Horizontal gaze orientation is associated with head movement in sagittal plane and this will assist consistent horizontal head placement. The horizontal T-square was positioned at 900 to the marked anatomical reference points, and position of the T-square bracket on the vertical ruler was marked on the LEMD with a marker.

Following this, they were instructed to assume their habitual cervical resting posture, which consisted of flexion and extending the cervical spine in three decreasing amplitude movements, until the usual resting posture of the head is obtained. Contact between their scapulae and the vertical backboard, and spotting the selected letter during each head sweep was maintained. By opening the screws and sliding the bracket, the horizontal T-square was fixed at 90° with the marked anatomical reference points and the position of the T-square bracket on the vertical ruler was marked on the LEMD with the marker. The readings were called out by one of the researchers for the recording assistant to put down in the recording sheet while one other researcher, who was the time keeper, stopped the stopwatch after this.

The test was carried out in the mornings and afternoons for four consecutive days on the same participants, and neither the participants nor the testers viewed the record sheet at the end of each day till the last day of the test to prevent bias or interference with the values obtained. Four measurements were taken at each test session: the horizontal and vertical movements at the superior most tips of the helix of the ear, and the horizontal and vertical movements at the spinous process of C7.

The vertical distances through which the T-square had travelled were read in centimeters (D1 and D3) from the vertical rulers beside each slot. The distance from the backboard to the superior most tip of the helix of the ear (D2), and from the backboard to the centre of the C7 spinous process (D4) was also measured in centimeters from the horizontal rulers. By combining the vertical and horizontal measurements occurring at the superior most tips of the helix of the ear (D1 and D2) and at the spinous process of C7(D3 and D4), the excursion angles at these anatomical points was calculated using the formula [1]:

$$\text{Tan } \Theta = \frac{\text{(vertical distance)}}{\text{(horizontal distance)}}$$

Data Analysis

Descriptive statistic including mean and standard deviation were used to summarise the data obtained from the LEMD. Pearson's product moment correlation coefficient was used to ascertain the relationships in the mean daily computed excursion angles measurement obtained (at both selected landmarks) within each paired days from the LEMD in the morning and afternoon; paired t–test was used to ascertain if there were any significant differences in the mean daily computed excursion angle measurements (at both selected landmarks) between each paired days from the LEMD in the morning and afternoon. Level of significance (alpha) was set at 0.05.

Results

A total of 46 participants (27 males and 19 females) were involved in this study. They were all apparently healthy individuals aged between 18 and 33 years old (22.3 ± 2.66 years). The demographic characteristics of the participants are presented in Table 1 below. Table

2 revealed no significant difference was found between mean daily readings and the computed excursion angles of day 1 and the other days obtained both for mornings and afternoons, with their p-value less than 0.05 in all cases except on day 3, suggesting consistency of readings obtained and possible reliability of the measurements.

Table 3 revealed that a significant (p<0.05) correlations exist at both measured landmarks in the afternoon readings between day 1 and 2 (r=0.247 and 0.316), day 1 and 3 (r=0.425 and 0.478), and day 1 and 4 (r=0.274 and 0.592) respectively.

Table 4 revealed that there was no significant difference between mean daily readings and computed excursion angles of morning and afternoon at both landmarks taken for the four days of measurement (p>0.05) in all cases, indicating possibility that the measurements were not affected by diurnal changes.

Characteristics	Male [n=27] X ± S.D	Female [n=19] X ± S.D	Total [n=46] X ± S.D
Age [years]	22.9 ± 2.73	21.4 ± 2.34	22.3 ± 2.66
Height [meters]	1.73 ± 0.07	1.64 ± 0.05	1.7 ± 0.08

KEY: X=Mean values of the characteristics of participants.
S.D=Standard deviations of the characteristics of participants.
N=Number of participants.

Table 1: Physical characteristics of participants.

Excursion Angles	time of day	paired day	N	X ± S.D A	X ± S.D B	t-value	p-value
Θx	Morning	1& 2	46	4.88 ± 2.67	5.06 ± 3.16	−0.340	0.735
	Afternoon	1& 2	46	5.37 ± 4.88	3.37 ± 3.26	0.835	0.408
Θy	Morning	1& 2	46	6.35 ± 4.63	6.16 ± 3.30	0.273	0.786
	Afternoon	1& 2	46	6.10 ± 5.32	7.06 ± 4.75	−1.108	0.274
Θx	Morning	1& 3	46	4.88 ± 2.67	4.51 ± 2.26	0.785	0.436
	Afternoon	1& 3	46	5.37 ± 4.88	4.27 ± 2.64	2.33	0.024*
Θy	Morning	1& 3	46	6.35 ± 4.63	5.06 ± 4.42	1.739	0.089
	Afternoon	1& 3	46	6.10 ± 5.32	5.78 ± 3.51	0.461	0.647
Θx	Morning	1& 4	46	4.88 ± 2.67	5.10 ± 2.64	−0.440	0.662
	Afternoon	1& 4	46	5.37 ± 4.88	4.62 ± 2.28	1.46	0.151
Θy	Morning	1& 4	46	6.35 ± 4.63	5.51 ± 3.22	1.222	0.228
	Afternoon	1& 4	46	6.10 ± 5.32	5.85 ± 3.09	0.401	0.691

KEY:
*p-value is significant at 0.05, A=first day of paired day, B=second day of paired day
N=number of participants, Θx=computed excursion angle of the superior most tip of helix of the ear. Θy=computed excursion angle of the spinous process of C7.

Table 2: comparison between day 1 with the other days mean daily computed excursion angles obtained in the mornings and afternoons at both landmarks.

Paired days		Measurements	R	p-value
1&2	morning	Θx(degrees)	0.273	0.066
	Afternoon	Θy(degrees)	0.32	0.030*
1&3	morning	Θx(degrees)	0.452	0.002**
	Afternoon	Θy(degrees)	0.478	0.001**
1&4	morning	Θx(degrees)	0.274	0.066
	Afternoon	Θy(degrees)	0.592	0.000**

KEY:
*p-value is significant at <0.05
r=correlation coefficient values
Θx=computed excursion angle of the superior most tip of helix of the ear.
Θy=computed excursion angle of the spinous process of C7.

Table 3: Pearson product moment correlation coefficients for day 1 with the other days mean daily computed excursion angles obtained at both landmarks.

Days	Measurements	N	Morning X ± (S.D)	Afternoon X ± (S.D)	t – value	p – value
1	Θx (degrees)	46	4.88 ± (2.67)	5.37 ± (3.37)	− 0.910	0.368
	Θy (degrees)	46	6.35 ± (4.63)	6.10 ± (5.32)	0.356	0.723
2	Θx (degrees)	46	5.06 ± (3.16)	4.88 ± (3.26)	0.331	0.742
	Θy (degrees)	46	6.16 ± (3.30)	7.06 ± (4.75)	−1.238	0.222
3	Θx (degrees)	46	4.51 ± (2.66)	4.27 ± (2.64)	0.693	0.492
	Θy (degrees)	46	5.07 ± (4.42)	5.78 ± (3.51)	−1.179	0.245
4	Θx (degrees)	46	5.10 ± (2.64)	4.62 ± (2.28)	0.992	0.327
	Θy (degrees)	46	5.51 ± (3.22)	5.85 ± (3.09)	−0.712	0.48

KEY:
*p – value is significant at < 0.05
Θx=computed excursion angles at superior most tip of helix of the ear.
Θy=computed excursion angles at spinous process of C7
X=Mean values of measurements
S.D=Standard deviations of measurements
N=Number of participants

Table 4: Comparison between morning and afternoon mean daily computed excursion angles obtained during the four days of measurement.

Discussion

The original LEMD was designed as a simple, portable, inexpensive and easily accessible device used in treatment setting for objectively assessing change in cervical posture over time. This will assist in describing the range of head postures found in the population, and in quantifying the effectiveness of physiotherapy intervention for posture related problems. However, because the concept of using LEMD for postural excursion angles has received less record in the literature, its universal use as a measurement tool by physiotherapy need more rigid scrutiny [1]. This study employed similar protocol as in Grimmer's study in 1993.

It was observed that the computed excursion angles obtained at both landmarks in the morning and afternoon showed no significant change except at the superior-most tip of helix of the ear in the afternoon between day 1 and 3, which may be attributed to error of parallax. However, this is somewhat in agreement with Grimmer [1] who reported absence of significant differences in the means of paired tests within the four days of measurement. The possibility of intra-rater differences was taken care of by having the same person take the readings for each particular participant. The absences of a significant difference in the computed excursion angles suggest that the LEMD may be a reliable instrument with possibility of repeatability of readings although this may have been as a result of the fact that the participants generally are persons of the same occupational leaning who have similar daily postural experiences.

The results revealed weak but significant correlations and temporal stability of computed excursion angles obtained from the adapted LEMD. This finding agrees with that of Grimmer [1] and Harrison [7] who both found high correlations and consistently high temporal stability of postural measurement from the LEMD. The difference in the strength of the correlation coefficient may be attributed to the population under study with regards to their occupational demands, individual genetics, anatomical construction, personality, muscle strength and endurance, and culture. These factors were opined by Grimmer-Somers et al. [8] to influence the different relative position that the individual cervical spinal segment assumes. The occupational demand of the population involved in the current study may have influenced the temporal stability of the excursion angles obtained. This may be because they assume different cervical resting postures with regard to when receiving a lecture, watching a movie, reading in the library, and reading at home either on the bed or using a table and a chair etc. Consequently, it is possible that the population under study, having similar occupation would not have a likelihood of wide variations in readings. Thus, it is not known the result of involving persons of different occupations and hobbies.

It was observed in this study that there was no significant change between measurements obtained in morning and afternoon for the four days. It thus suggests that the LEMD is sensitive enough to produce repeatable measure in the morning and afternoon despite the change in diurnal temperature and physical activity that the individual may be engage in, which might influence the strength and endurance of cervical muscles as opined by Grimmer-Somers et al. [8].

In line with previous study by Grimmer [1] the use of this device proved to be time efficient as it took an average sum of 145 seconds to take each participant measurement. It also proved to be relatively cost effective as it took approximately the sum of fifteen thousand naira (N 15,000.00 or approximately $41 only) to manufacture the device, supporting the assertion that the LEMD is relatively cost effective, time efficient and reliable. However, more studies should be done and recorded in literature amongst different populations as regard to their occupational demand, culture, mental status, and cervical pathological conditions.

Conclusion

Linear Excursion Measurement Device (LEMD) is a reliable, time efficient and low-cost device which can be used by physiotherapists in clinical settings as objective feedback of monitoring improvement occurring with physiotherapy intervention and can serve as objective

evidence-based measure of intervention in management of cervical postural dysfunction or other posture-related problems.

Linear Excursion Measurement Device (LEMD) also demonstrated the temporal stability and reliability of the computed cervical excursion angles with diurnal changes having no effect on obtained computed excursion angles. Thus, the readings on the device do not vary with the time of day.

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