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The Manual Tests that can Elicit the Strongest Responses from the Palmaris Longus Muscle.

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ABSTRACT

The relative effectiveness's of the individual ten tests of the palmaris longus muscle (PLM) have not been compared. The main aim of the study is to determine the most effective tests, that will recruit the PLM the most, and to motivate and encourage clinicians and researchers to use them. The electromyographic (EMG) activity of the PLM was recorded during each of the ten tests on 30 arms, to find the tests that recruited the PLM the most. In addition, the consistencies of the ten tests in producing the same surface anatomical prominences were observed on an additional 80 arms. The surface anatomical prominences were classified into six patterns. Only two of the ten tests, the Gangata Test and the Resisted Wrist-Flexion Test, performed satisfactorily on the EMG and the Classification kappa agreement test. The simultaneous use of the Resisted Wrist Flexion Test and the Gangata Test is being recommended for clinical and research purposes of the PLM. The classification system should improve the quality of the clinical assessments of the PLM.

Key words: palmaris longus, thumb abduction, electromyography, clinical tests

Surgeons commonly use the palmaris longus muscle (PLM) to reconstruct damaged ligaments, tendons and muscles, and consequently the palmaris longus muscle (PLM) is the most commonly used/harvested tendon and muscle autografts (MacDougal 1995). The PLM is usually assessed manually prior to the surgery and there are currently ten different Manual Muscle Testings (MMTs) for determining the presence and prominence of the PLM. However, to the best of our knowledge, the relative effectiveness of each of these ten tests has never been compared, which has led to uncertainty among clinicians as to which is the most valid test.

The PLM, a muscle of the forearm, is the most variable muscle in humans (Reimann et al 1944). The PLM arises from the medial epicondyle of the humerus from a relatively small muscle belly and has a long tendon that inserts onto the palmar aponeurosis and thenar eminence (Standring 2005). Of the many variations of the PLM, the most frequent is the absence of the PLM 2. The rate of palmaris longus absence varies widely in different ethnic groups with absence in 22% of Whites, 3% of Blacks and 5% of Asians respectively (Sebastin et al. 2005). The other variations of the PLM include the varying number and position of the muscle belly and/or tendon, and insertion of the tendon (Reimann et al. 1944). Although the PLM helps in wrist flexion, tensing of the palmer aponeurosis and has a significant role in thumb abduction; the PLM is regarded as functionally negligible (Standring 2005, Fahrer 1973, Gangata et al. 2009a).

Schafer (1909) was the first to develop a test for determining the presence of the PLM. There has been a recent flurry of new manual techniques to test for the presence of the PLM tendon, and there are currently ten tests that have been described to assess the PLM. The formal descriptions of the ten tests are presented in Table 1.

Objectives

Manual muscle testing (MMT) is the assessment of normal, injured or paralyzed individual or groups of muscles. MMT ought to be highly reproducible by the same person and by other persons, and should recruit the targeted muscle as much as possible (Janda 1983). A muscle should have the highest electromyographic (EMG) activity, when executing a primary function in comparison to secondary or synergery functions, since each muscle in the body is a primary mover for a very specific action (Janda 1983). Meanwhile, the primary function of the PLM is currently not clear among wrist flexion, tensing of the palmer aponeurosis and thumb abduction (Standring 2005, Fahrer 1973, Gangata et al. 2009a). Hence, the most effective MMT for assessing the PLM should have the highest EMG readings because it will be the best at executing the primary function of the PLM. The current study aims to determine which of the ten MMTs best elicits the main action of the PLM by comparing the electromyography readings during the tests.

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Table 1: The ten methods of testing for the presence of the PLM

Name of test techniques	Basic test description	Wrist position	Finger position	References
Traditional Test or 'Three-Finger Test'	Opposition of thumb and little finger test	Slight wrist flexion	The tip of the thumb opposes the tip of the Fifth finger	Schaffer 1909, Zeybek et al. 1998, Bhattacharya 2005.
Mishra's Test I (Adducted five finger test)	Resisted active flexion of the wrist, while the rest of the fingers are adducted	Wrist flexion	Passive hyperextension of the PIP joints and the DIP joints of all the five fingers	Kendall and Kendall 1971, Mishra 2001, Standring 2005
'Fisted-Hand Test'	A fisted hand with the thumb on the fourth finger	Wrist in neutral position	The distal finger pad of the thumb presses on the dorsal middle phalange of the fourth and fifth fingers, which are flexed	Lehmkuhl et al. 1972, Bhattach-arya 2005,
Mishra's Test II	Thumb abduction against resistance with the wrist in slight flexion	Slight wrist extension	The thumb is in abduction and pronation. The DIP and PIP joints of the medial four fingers are in extension and the MCP joints is in a neutral joint position.	Mishra 2001
Two-Finger Test'	The thumb opposes flexed fourth and fifth finger while the index and the middle finger are extended	Wrist in neutral position	The DIP and PIP joints of the index and third fingers are in extension and the MCP joints in a neutral position. The distal finger pad of the thumb presses on the dorsal middle phalange of the forth and fifth fingers, which are flexed.	Pushpakumar et al. 2004, Bhattacharya 2005, Mahajan 2005.
'Fingers-Fan-out' Test.	The hand opens out all the fingers	Slight wrist flexion	All the DIP and PIP joints of the five fingers are extended, while the MCP joints are in neutral position.	Bhattacharya 2005, Mahajan 2005.
Lotus Test	All the fingers are brought into a cone shape.	Slight wrist Flexion.	The DIP and PIP joints of the medial four fingers are in extension and the MCP joints in flexion, while the thumb is abducted.	Bhattacharya 2005.
Resisted wrist flexion Test	Wrist flexion with manual resistance placed on the mid-palmar surface.	Wrist flexion	Neutral position of the PIP, DIP and MCP joints of all the five fingers.	Bhattacharya 2005.
'Four-Finger Test'.	Strong thumb abduction and extension of the rest of the other fingers.	Slight wrist extension.	The thumb is in abduction and pronation. The DIP and PIP joints of the medial four fingers in extension, while the MCP joints in neutral.	Oudit et al. 2005.
Gangata Test	Resisted thumb abduction and resisted wrist flexion.	Slight wrist Flexion.	Thumb is in abduction and pronation. The DIP and PIP joints of the medial four fingers are in extension and the MCP joints in a neutral position.	Gangata 2009b.

PIP = proximal interphalangeal joint; DIP = distal interphalangeal joint; MCP = metacarpophalangeal joint

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MATERIALS AND METHODS

This study comprised two approaches: electromyography (EMG) and the Classification kappa agreement test. The EMG part compared the EMG activity of the PLM with each of the ten tests. The Classification kappa agreement test compared the reliability of a new classification system that assesses the degree of visibility of the tendons of the PLM and flexor carpi radialis (FCR) across the ten tests.

Subjects

Ethical permission to carry out the study was granted by the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town. Sixty healthy students (20 for the EMG test and 40 for the Classification kappa agreement test of the study) from the University of Cape Town were screened. The subjects had no compromised function, injury or scars on the forearms or hands. The inclusion criterion for the EMG test was the bilateral presence of the PLM, and was assessed by using both the Traditional Test and the Gangata Test, while the Classification kappa agreement test did not have inclusion criteria. Of the 20 subjects who were approached for the EMG test, two wished not to take part in the study and three did not complete all the individual tests due to time constraints, resulting in a study sample of 15 participants. The PLM was tested on both the left and right sides in 15 participants, all of whom were right hand dominant. Ten of the participants were male and five were female. Most of the participants were between the ages of 17 and 21 years, except for one participant who was 30. All 40 students completed the Classification kappa agreement part. All the images presented in the current manuscript were obtained during the course of the study.

Procedure

The right and left forearms of each of the fifteen subjects were assessed for the strength of electrical activity of the muscle belly of the PLM during contraction using electromyography (EMG). A small portable EMG unit (*NeuroTrac 1™, Model ECS 100, Verity Medical LTD, Made in UK*) was used. An area covering the proximal one-third of the forearm (from the medial epicondyle) was cleaned with an alcohol swab, to remove sweat and dirt. To isolate the PLM belly, a transverse straight line across the wrist was drawn using a non-permanent marker and linked the pisiform bone to the trapezium bone. A second dotted line was then drawn from the medial epicondyle of the humerus to the intersection with the transverse wrist line, along the tendon and muscle of the PLM. The length (cm) of this line was measured and recorded. The position of placement of the two electrodes was determined by calculating the 75th and the 85th percentiles of the length from the wrist to the medial epicondyle. The margins of the belly of the PLM were palpated and outlined by asking the subject to perform thumb abduction using the Four Finger Test. Plastic ring-reinforcers were placed at the two calculated electrode points along the dotted line (75th and the 85th percentiles of the length from the wrist to the medial epicondyle). Plastic tape was placed around the ring-reinforcers, to prevent the electrodes making contact with other areas of the skin that did not lie over the PLM belly and thus ensure that the EMG signals from the other muscles of the forearm did not affect the EMG signals of the PLM. The elbow was positioned at about 120 degrees in all tests, to standardize the tension of the PLM, which crosses over both the wrist and elbow joints. The two small electrodes were placed on the skin over the ring-reinforcers, after a drop of conductive gel was placed at the centre of the ring-reinforcers to improve the conduction of the electrical signal, as shown in Figure 1.

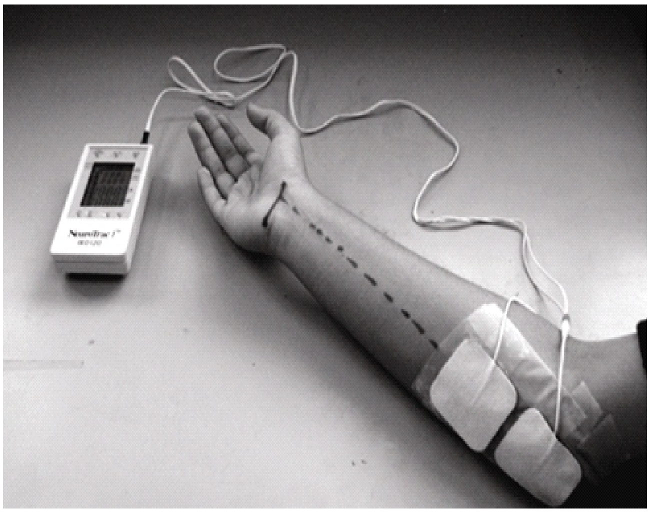

Figure 1: EMG and electrodes

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Before the actual tests were begun, the subjects were taught the ten different techniques with the help of visual aids. After a short warm-up period, each subject was asked to perform a maximum contraction of the PLM, while looking at the respective visual aid of the test being done. There were three periods of relaxation (each lasting five seconds) separating the two contractions of the PLM. The relaxation periods were interspaced by two periods of contraction (work), each lasting for three seconds. A resting period of one minute was allowed between subsequent clinical tests to reduce muscle fatigue. The sequence of each clinical test was randomized between participants and after each arm was tested. Randomization was meant to factor out the effects of muscle fatigue on the last few tests of the ten tests. The visual aids of the ten methods were shuffled before each arm was tested and enabled the order of each test of the ten tests to be randomized. The method generating the highest EMG readings (micro volts) was considered the most effective method of the ten methods for testing the PLM.

The EMG readings were normalized by the Maximum Voluntary Contraction (MVC) of the PLM. The MVC of the PLM was the strength of thumb abduction and was measured using a dynamometer. The thumb was placed at 60 degrees of thumb abduction (Mishra's Test) and at 120 degrees of flexion, as shown in the Figure 2. Participants were asked to maximally abduct their thumbs against the dynamometer, while their hands and wrists were held down firmly to ensure that only thumb abduction strength was measured.

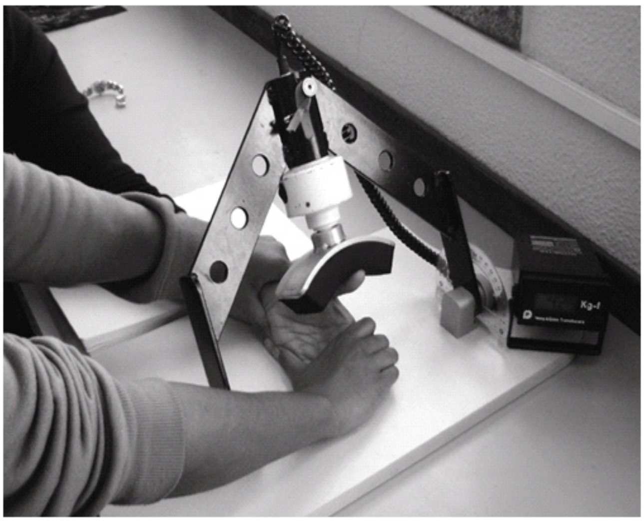

Figure 2: Testing strength of thumb abduction

A new classification system for the PLM

A classification system of the clinical presentations of the PLM has been developed. The tests used to assess the PLM may either allow one to observe the tendons of the PLM and flexor carpi radialis (FCR) or may fail to show one or both of the tendons of the PLM or FCR (Eric et al 2009). Consequently, some authors have used multiple tests for PLM, as the reliability and effectiveness of each test is unknown (Mbaka & Ejiwunmi 2009, Eric et al 2009). The proposed classification aims to resolve the problem and depends on whether the tendons of the PLM or FCR are visible or not during a test for the PLM, and the possible patterns are shown in Table 2.

Two pairs of examiners assessed the patterns and each pair of examiners comprised a graduate with a Masters in Anatomy and a second-year medical student. Each of the ten tests was assessed on both wrists of the same subject.

Statistics

Prior to the data collection, the reliability of the readings of strength of thumb abduction and the EMG readings was analysed using Kendall's Coefficient of Concordance, as a measure of agreement. The EMG readings of the ten tests of the same forearm were repeated after 30 minutes in 20 forearms of ten subjects with the bilateral presence of the PLM. Two separate groups of subjects were used for the reliability of the EMG and thumb abduction. The reliability of the new proposed classification was carried out after the data collection using Kendall's Coefficient of Concordance. The presentation pattern that was generated by a test was compared to the presentation pattern obtained by the majority of the ten tests (reference pattern) and the agreement was calculated. The results of the ten tests were analyzed to determine if they were statistically significantly different from each other using the ANOVA and a post-hoc test was performed to determine if the 9 tests were statistically different from the Traditional Test.

Table 2: Classification of the patterns of the clinical presentation the PLM

Type I (PLM tendon present)	Type II (PLM tendon absent)
Type Ia - Both the PLM and FCR are visibly present.	Type IIa - The FCR is visibly present and the PLM is absent.
Type Ib - Only the PLM is visibly present and the FCR can be located by palpation.	Type IIb - The FCR is not visibly present and can only be located by palpation. The PLM is absent.
Type Ic - Only the FCR is visibly present and PLM can be located by palpation.	
Type Id - Both the PLM and FCR are not visibly present and can only be located by palpation.	

RESULTS

EMG Results

The average strength of thumb abduction (kilogram force) from the three readings was greater in the males than in females participants, at 2.65 ± 0.70 kg and 1.09 ± 0.39 kg respectively (Mann-Whitney U Test, p = 0.000012). The average length of the PLM from the medial epicondyle to the wrist was longer in males than in females, at 29.8 cm ± 1.17 cm, and 26.7 cm ±1.78 cm respectively (Mann-Whitney U Test, p = 0.00099). The reliability of the EMG readings of the ten tests and of the strength of thumb abduction was very high (kappa = 0.88, p = 0.0049 and kappa = 0.95 p = 0.01) respectively using the Kendall's Coefficient of Concordance.

An ANOVA analysis of the ten tests revealed that there were statistically significant differences between the normalised EMG work of the ten tests (p = 0.00) and that Mishra's Test I, Mishra's Test II, Resisted Wrist Flexion Test and the Gangata Test had the highest four EMG readings, as shown in Figure 3 below.

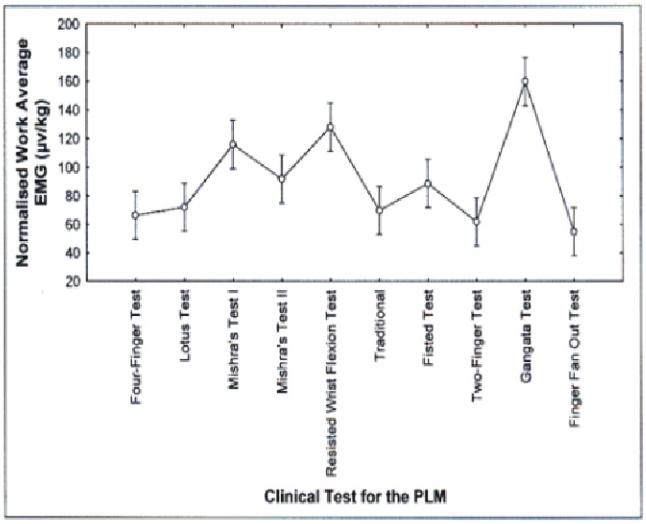

Figure 3: Normalised EMG Work Comparability of the tests to each other using the ANOVA (µv/kg, n = 30). One way ANOVA test; Unweighted Means, current effect: F (9, 290)=15.562, p=0.00. The bars denote the 95% confidence intervals.

An ANOVA post-hoc Tukey HSD test indicated that only the normalised EMG work of the Mishra's Test I, Resisted Wrist Flexion Test and the Gangata Test were significantly higher than that of the Traditional Test, as shown in line 6 of Table 3. The Traditional Test has been the benchmark for testing the clinical presence of the PLM, and thus all the tests were compared to it .

A new classification system for the PLM

The Four Finger Test, Two Finger Test, Mishra's I Test and the Gangata Test had very good kappa agreements, with kappa values of above 80%, and the remaining Tests showed a good kappa agreement with kappa values between 60% and 80%, as shown in Figure 4.

Among the MMTs, the patterns of Type Ia, Type Ib and Type IIa had good kappa agreement (kappa was between 60% and 80%), the Type Id pattern had poor kappa agreement (kappa was between 40% and 60%) and in overall, the six patterns had a good kappa agreement (kappa was between 60% and 80%), as shown in Figure 5. A 'reference pattern' was defined as when at least five of the ten MMTs reflected a particular pattern for a given wrist. Type Ic and Type IIb patterns failed to provide a 'reference pattern' in all the forearms examined and thus failed to generate a kappa agreement score, as shown in Figure 5.

Table 3: The Tukey HSD test (an ANOVA Post Hoc Test, between MS = 2204.4, df = 290.00) of comparing the means of the ten tests. The benchmark, the Traditional test, is in a bold font.

Test	Four-Finger Test	Lotus Test	Mishra's Test I	Mishra's Test II	Resisted Wrist Flexion Test	Traditional Test	Fisted Hand Test	Two-Finger Test	Gangata Test	Fan-Out Test
1. Four-Finger Test		1.00	0.00	0.51	0.00	1.00	0.70	1.00	0.00	1.00
2. Lotus Test	1.00		0.01	0.83	0.00	1.00	0.93	1.00	0.00	0.92
3. Mishra's Test I	0.00	0.01		0.61	0.99	0.01	0.43	0.00	0.01	0.00
4. Mishra's Test II	1.00	0.83	0.61		0.08	0.72	1.00	0.28	0.00	0.07
5. Resisted Wrist Flexion Test	0.00	0.00	0.99	0.08		0.00	0.04	0.00	0.22	0.00
6. Traditional Test	1.00	1.00	1.00	0.72	0.00		0.87	1.00	0.00	0.97
7. Fisted Hand Test	1.70	0.93	0.43	1.00	0.04	0.87		0.44	0.00	0.14
8. Two-Finger Test	1.00	1.00	0.00	0.28	0.00	1.00	0.44		0.00	1.00
9. Gangata Test	0.00	0.00	0.01	0.00	0.22	0.00	0.00	0.00		0.00
10. Fan-Out Test	1.00	0.29	0.00	0.07	0.00	0.97	0.14	1.00	0.00	

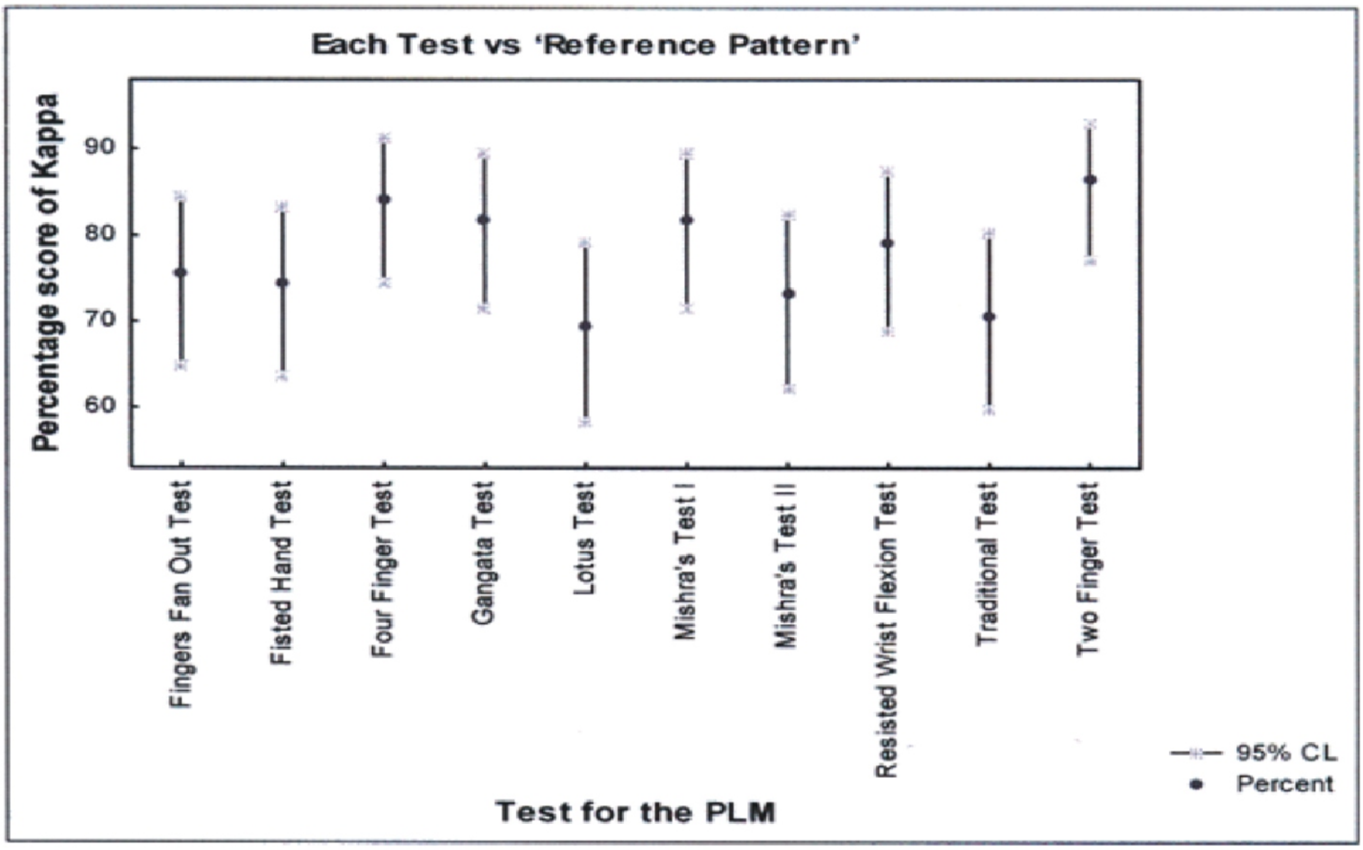

Figure 4: Kappa agreement of the classification system of the patterns presentations generated by the ten tests.

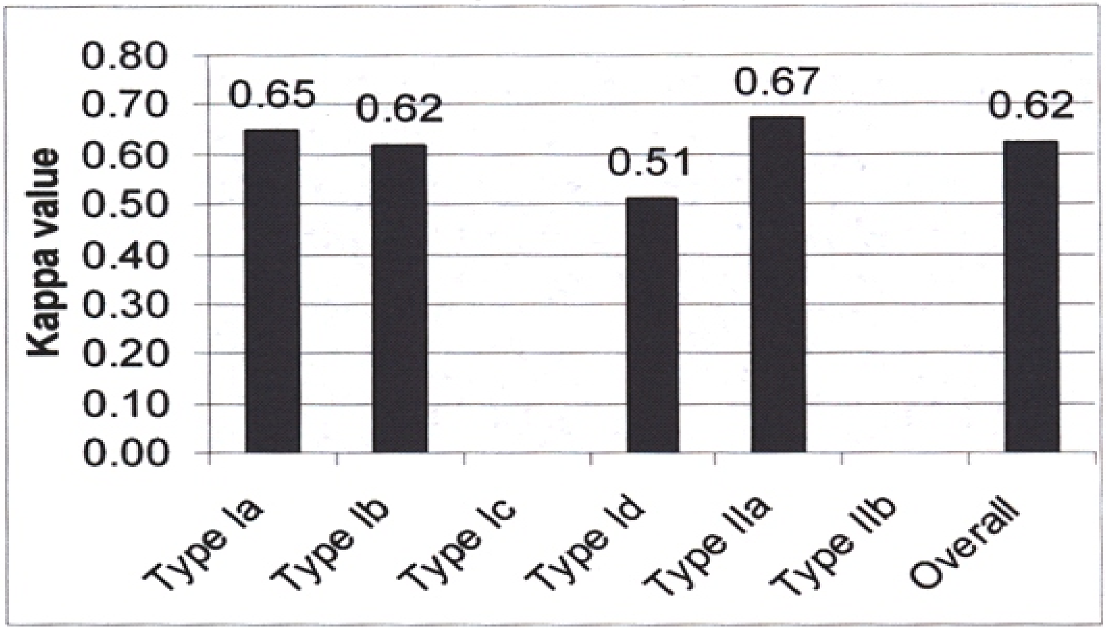

Figure 5: Kappa agreement levels of the ten Tests to the 'Standard Patterns'.

DISCUSSION

An array of tests of varying efficacies of the same muscle might lead to different results from studies, and may account for a portion of the variation in frequency of absence of the PLM. Furthermore there has been a tendency for authors to use multiple tests due to lack of consensus of the most effective test. A lack of confidence in the tests for the PLM has resulted in researchers several tests. Mbaka and Ejiwunmi (2009) and Eric et al (2009) used four tests and five tests on each arm respectively. The reliability of the portable EMG that was used was first evaluated before the commencement of the study. A very good level of inter-rater agreement was obtained, indicating that the EMG readings were reliable.

Of the ten tests, only the four tests that required resistance (Mishra's Test I, Mishra's Test II, Resisted Wrist Flexion Test and the Gangata Test), had the four highest EMG using the ANOVA analysis. The use of manual resistance in the tests of the PLM made the muscle work harder, thus producing more EMG activity than the other tests which did not feature such manual resistance. All the three tests with the highest EMG (Mishra's Test I, Resisted Wrist Flexion Test and the Gangata Test) had resisted wrist flexion, and in addition, the first (Gangata Test) and fourth highest (Mishra's Test II) had resisted thumb abduction. The Gangata Test yielded the greatest EMG Average Work Performed results among the ten tests and was the test that elicited the strongest contraction of the PLM. The Gangata Test was the only test that incorporated all three functions of the PLM (thumb abduction, wrist flexion and tension of the palmar aponeurosis) against resistance (Gangata, 2009b). None of the other nine tests simultaneously involved the three functions of the PLM. According to Janda (1983), each muscle is a prime mover of a specific action/s. The authors are of the belief that the primary roles of the PLM are wrist flexion and thumb abduction (after analyzing the results of the tens tests), and MMT that incorporate these actions would elicit the highest activity of the PLM. Standring et al (2005) differed and believed that primary action of the PLM is encouraging the skin to act as an anchor for horizontal shearing forces, without presenting empirical research evidence.

An ANOVA post-hoc Tukey HSD test revealed that the normalised EMG work of the Mishra's Test II, Resisted Wrist Flexion Test and the Gangata Test were statistically significantly different from the Traditional Test. The Traditional Test has been taken as the bench mark for the manual testing of the PLM because it is the most commonly used test among studies testing the PLM Schaeffer 1909; Zeybek et al 1998, Bhattacharya 2005). Cross-talk occurs when electrical activity of adjacent muscles interferes with the EMG signals of the muscle being tested. The influence of the cross-talk from the other wrist flexors appears to be negligible, as the fisted test, which recruits most of the wrist flexors against resistance, still recorded a relatively low EMG signal of the PLM, as reflected on Figure 3. Performing EMG evaluations to the PLM on every patient is not clinically useful and is very tedious, but is helpful in selecting and advocating for the new bench mark test for assessing of the PLM.

A classification system of the PLM was created by the first author of the current paper and has appeared in Ndou et al., 2010. The classification system has six patterns and highlights the clinical variation of the PLM. The current paper has broadened and increased the use of the classification system to ten tests, unlike to only three tests as in Ndou et al., 2010. Ignoring the classification patterns may cause inaccurate assessments of the PLM by clinicians and researchers with limited experience in the tests of the PLM. The current study has confirmed that type 1c, 1d and 2b have the lowest consistencies, as was found by Ndou et al., 2010. A common feature of the pattern types with the three lowest levels of kappa agreements was that the PLM could only be identified by palpation. Failure to correctly palpate a PLM may result in the muscle being incorrectly recorded as absent. Extra care during palpation has to be taken to correctly distinguish the tendon of the PLM from the tendons of the flexor digitorum superficialis and flexor carpi radialis muscles. The variation in prominence or poor visibility of adjacent tendons (flexor carpi radialis and flexor digitorum superficialis) at the wrist may confuse clinicians when correctly evaluating the presence of the PLM. The tendon of the PLM might also exhibit varying levels of prominence. Using a particular universal standard test/s for the PLM will greatly improve agreement between the tests and encourage a more careful examination of tendons on the anterior aspect of the wrist.

Only three tests (Mishra's Test II, Resisted Wrist Flexion Test and the Gangata Test) of the ten performed satisfactorily on ANOVA post-hoc Tukey HSD analysis for the EMG part of the study. Mishra's Test II is not being recommended because it is a poor differentiator between the six patterns. Thus, the authors are recommending the dual use (to improve their individual efficacy) of the highest two, the Resisted Wrist Flexion Test and the Gangata Test, for clinical and *in vivo* research assessment of the PLM, as shown in Figures 6 and 7. The Resisted Wrist Flexion Test has been described as one of the simplest tests of the PLM that a patient can understand, and that a clinician can carry out (Bhattacharya 2005), while the Gangata Test is relatively more difficult to perform but elicits a stronger response from the PLM. The recommended two tests yielded the strongest results and showed good kappa agreement in differentiating the six patterns.

Figure 6: Resisted Wrist Flexion Test (Bhattacharya 2005)

Figure 7: Gangata Test (Gangata 2009b)

The other eight tests (including the Traditional Test) should be discouraged from use because they are relatively poorer recruiters of the PLM when compared to the other tests. For almost 100 years, the Traditional Test (Schaeffer 1909), has been the prime test for the PLM, despite having no anatomical rational (Bhattacharya 2005), The current study has confirmed the Traditional Test to be a poor recruiter of the PLM. A major drawback of the Traditional test is that it performs only one of the three functions of the PLM. The Traditional Test performs traction of the PLM and does not assist wrist flexion nor thumb abduction. Moreover, the Traditional Test is a relatively complex hand maneuver for the patients to perform (Pushpakumar et al. 2004).

The advantage of a specific manual muscle test when compared with other manual tests is generally difficult to quantitatively assess and, consequently, most MMTs used on patients by clinicians are yet to be evaluated with basic research. The methodology of the current study based on electromyography is a reliable option to emulate. It is believed that when the PLM contracts, the magnitude of the EMG and the prominence of the tendon would increase. The technique could be applied to subcutaneous muscles, whose tendons rise to span the concavity of body depressions when the muscles are contracted. The technique cannot be applied to deeper muscles. The tendons of the gastrocnemius, tibialis anterior, quadriceps femoris, biceps brachii, triceps brachii and the flexor digitorum superficialis muscles should be suitable for assessment with the same technique.

The main concern being addressed by the current paper is to encourage clinicians and researchers to use the same tests, as each of the ten MMTs of the PLM may produce different prominences of tendons at the wrist. The presentations may be due to variable prominences or non appearance of either the PLM tendon or the adjacent wrist flexor tendons during the ten tests. It is consequently the various combinations of surface anatomical appearances of tendons that clinicians depend on to make their judgment of whether the PLM is present or not.

The simultaneous use of the Resisted Wrist Flexion Test and the Gangata Test is being recommended for clinical and research purposes. The Traditional Test and the other seven tests are apparently less effective, because they either relatively poorly recruiters of the PLM or have relatively poorer kappa agreement between the presentational patterns of the PLM. Use of the newly described classification system of the PLM is expected to improve the quality of the clinical assessments of the PLM. Future study could reveal how easily these tests are learned, whether they are correctly performed and whether the tests are affected by the position of the wrist.

REFERENCES

Erić M, Krivokuća D, Savović S, Lekšan I, Vučinić N (2010). Prevalence Of The Palmaris Longus Through Clinical Evaluation. Surg Radiol Anat; **32**(4): 357-61.

Fahrer M (1973). The Role Of The Palmaris Longus Muscle In The Abduction Of The Thumb. J Of Anat (London); **116** (Pt3): 467.

Gangata H, Ndou R, Louw G (2009a). An Investigation Into The Contribution Of The Palmaris Longus Muscle To The Strength Of Thumb Abduction. Clin Anat; **22**(2): 275.

Gangata H (2009b). The Clinical Surface Anatomy Anomalies Of The Palmaris Longus Muscle In The Black African Population Of Zimbabwe And A Proposed New Testing Technique. Clin Anat; **22**(2): 230-5.

Janda V (1983). *Muscle Function Testing.* 1st Ed. London: Butterworth.

Kendall HO, Kendall PF, Wadsworth GE (1971). Muscles & Function. 2nd Ed. Baltimore: Williams & Wilkins.

Lehmkuhl DL, Smith LK (1972). Brunnstrom's Clinical Kinesiology. 4th Ed. Philadelphia: F. A. Davis Company;.

Macdougal BA (1995). Palmaris Longus Opponensplasty. Plast Reconstr Surg; **96**(4): 982-984.

Mahajan AL (2005). The 'Fingers Fan Out' Sign: Stick Out Your Palmaris Longus Even Better! Br J Plast Surg; **58**(2): 278-279.

Mbaka GO, Ejiwunmi AB (2009). Prevalence Of Palmaris Longus Absence - A Study In The Yoruba Populatio. Ulster Med J; **78**(2): 90-93.

Mishra S (2001). Alternative Tests In Demonstrating The Presence Of The Palmaris Longus. Indian J. Plastic Surg; **34**: 12.

Ndou R, Gangata H, Mitchell B, Ngcongo T, Louw G (2010). The Frequency Of Absence Of Palmaris Longus In A South African Population Of Mixed Race. Clin Anat. May;**23**(4):437-42

Pushpakumar SB, Hanson RP, Carroll S (2004). The 'Two Finger' Sign. Clinical Examination Of Palmaris Longus (PL) Tendon. Br J Plast Surg; **57**(2): 184-185.

Oudit D, Crawford L, Juma A, Howcroft A (2005). The

"Four-Finger" Sign: To Demonstrate The Palmaris Longus Tendon. Plast Reconstr Surg; **116**(2): 691-692.

Reimann AF, Daseler EH, Anson BJ et al (1944). The Palmaris Longus Muscle And Tendon. A Study Of 1600 Extremities. Anat. Rec; **89:** 495-505.

Schaeffer JP (1909). On The Variations Of The PLM. (An Abstract). Anat. Rec; **3**: 275-278.

Schmitt WH Jr, Cuthbert SC (2008) Common Errors And Clinical Guidelines For Manual Muscle Testing: "The Arm Test" And Other Inaccurate Procedures. Chiropr Osteopat 16, 16.

Sebastin SJ, Puhaindran ME, Lim AY, Lim IJ And Bee WH (2005) The Prevalence Of Absence Of The Palmaris Longus; A Study In A Chinese Population And A Review Of The Literature. J Hand Surg [Br]; **30**(5): 525-527.

Standring S (2005). Gray's Anatomy. 39th Ed. London: Churchill Livingstone;.

Zeybek A, Gurunluoglu R, Caddar S et. al. (1998). A Clinical Reminder: A Palmaris Longus Muscle Variation. Annuls Of Plastic Surg; **41**(2): 224-225.