International Journal of Health Sciences and Research
Vol.13; Issue: 10; October 2023
Website: www.ijhsr.org
Original Research Article *ISSN: 2249-9571*

Evaluating Core Muscle Strength for Transversus Abdominis Among Normal Individuals - An Observational Study

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DOI: https://doi.org/10.52403/ijhsr.20231005

ABSTRACT

Background: Lack of control in deep muscles may result into poor segmental support even during activities of daily living in people with or without history of low back pain. This states the importance of muscular system in control of spinal stability.
Aim: To evaluate and estimate core strength of lumbar region in normal individuals.

Methods and Material: Cross sectional observational study with convenience sampling was carried out on 843 normal healthy individuals between the age group of 18 – 60 years. Core strength was estimated by pressure biofeedback unit with individual in prone formal test to assess transversus abdominis. Pressure reduction which was held at least up to 10 seconds was noted. The same procedure was repeated for three times and the best of the three repetitions was used for analysis.
Statistical analysis: MedCalc version 19.7.4 was used. Reference ranges were calculated with 90% CI with non-parametric percentile method.

Results: Reference range was 2 – 10 mmHg with median 9 mmHg for all the subjects between the age group of 18-60 years. Reference range for males (5 – 10 mmHg) was higher than females (2 – 10 mmHg) among this age group. Median for males and females was 10 mmHg and 6 mmHg respectively. Reference ranges was 5 – 10 mmHg for 18 – 30 years, 2 – 10 mmHg for 31 – 40 years and 41 – 50 years respectively and 2 – 9 mmHg for 51 – 60 years age groups.
Conclusions: Reference range for the core strength of lumbar region among normal individuals as measured by pressure biofeedback unit is 2 – 10 mmHg.

Keywords: Core strength, Pressure biofeedback unit, Reference range, Transversus abdominis

INTRODUCTION

Conceptual model of spinal stability comprises of active subsystem, passive subsystem and neural control.[1] Passive subsystem includes osseoligamentous structures of spine, active subsystem includes muscles that generate force to provide mechanical ability to stabilize spine and neural control is provided by nervous system which coordinates muscle activity in advance of predictable challenges and responds to afferent feedback to unpredictable challenges. These three subsystems are interdependent on each other and dysfunction in any one of them may lead to instability of spine. Trunk muscles are classified based on their function and location (superficial and deep). Lack of control in deep muscles may result into poor segmental support even during activities of daily living in people with or without history of low back pain. This states the importance of muscular system in control of spinal stability.

There is diversity of protocols used to assess core stability ranging from laboratory tests taking place in biomechanics or engineering laboratory to clinical/field test taking place in clinics, rehabilitation centres and sports centres. Laboratory methods include Real time ultrasound imaging, Fine wire EMG, Surface EMG and Isokinetic measures of strength. Clinical tests include Palpation test, Wisbey and Roth grading system, Pressure Biofeedback Unit (PBU) test to evaluate Transversus Abdominis (TrA) function,[2] abdominal fatigue test, Biering Sorenson test, Double Leg Lowering (DLL) test, side plank, prone plank, trunk curl[3,4,5] Sahrmann's grading using PBU, three plane core strength test, one leg standing balance test, one leg squat test, star excursion balance test.[6,7] PBU is a type of biomechanical biofeedback which helps to retrain muscle activity and provide visual biofeedback. It is relatively inexpensive, non-invasive, portable and easily applied in a clinical setting in comparison to various other techniques. It is a useful tool to assess deep abdominal function.[8] PBU is used in abdominal drawing in test to measure activation, strength and endurance of TrA.

Core strength is the ability of a muscle to exert or withstand force. Regulation of these forces in surrounding muscles results in active control of spinal stability. There are no standard ways to measure core strength.[6,9,10] Despite widespread use of core stability exercises in our set up, methods of clinical assessment of core strength are limited. Moreover, there is inconsistency in literature about what is the normal pressure reduction during the prone formal test for TrA. There are various methods to assess core muscles ranging from fine wire electromyography to palpation techniques. Certain methods require use of sophisticated equipment, making them impractical to use in the clinical set up. There is a need to examine core muscles in clinical or field setting with a non-invasive, portable, cost effective and easy to administer technique. There is a need to measure core strength in clinical set up as there is difference of thoughts regarding particular reference value for core strength in normal individuals. Through this study, PBU will be used to establish reference values for core muscles in individuals with age 18-60 years. This study will further provide reference ranges of core muscles based on age and gender.

For the purpose of this study core strength is defined as Pressure drop-in PBU due to isometric contraction of core muscle (Transversus Abdominis) measured in mmHg. Normal individuals are defined as Asymptomatic individuals with respect to musculoskeletal pain.

Thus, the aim of the study is to evaluate and estimate Core Strength (Transversus Abdominis) using PBU among normal individuals.

MATERIALS & METHODS

The study had approved by M P Shah medical college, institutional ethical committee, Jamnagar (Dissertation Protocol no. 20/5/14). Design of the study was Observational analytical study; Cross-sectional study. 1010 subjects were enrolled for the study by convenience sampling. Out of them 167 were excluded based on exclusion criteria. So, the total subjects analyzed were 843. Sample size was calculated based on guidelines for determining reference range by clinical and laboratory standards institute (CLSI).[11]

Subjects included in the study were both male and female volunteers between the age group of 18 – 60 years. Subjects with any of the following conditions were excluded such as Low back pain, Lumbar spine surgery, Pregnancy, Severe kyphosis or scoliosis, Spinal stenosis, Neurological disease, Cancer, Trauma to the lumbar spine and Nerve root entrapment.

Subjects were selected for the study as per the inclusion criteria from the city of Jamnagar, Gujarat, India. Subjects were called for the study through mouth-to-mouth publicity. Then on the basis of inclusion and exclusion criteria final subjects participated in the study. Each subject filled out the

Subject Information sheet and signed informed consent form (in vernacular language if needed). Demographic data such as age, gender, weight and height were taken of the subject.

Assessment of Core strength was done by assessing strength of TrA with PBU. [12,13,14] Before using it, reliability of PBU was measured and found to be moderate to excellent reliable.[15] To avoid bias, the same machine was used throughout the study. Calibration of the machine was done before using the machine.[16]

Familiarization was done with description of the task and demonstration of test performance. Proper rest period was given before commencement of the actual task to avoid the effect of fatigue. The actual task i.e., abdominal draw in test was performed with the subject in a prone lying position on the hard surface with arms by the side and the PBU was placed under the abdomen with the navel in the centre and the distal edge of the pad in line with the right and left anterior superior iliac spines. The PBU was then inflated up to 70 mmHg and was allowed to stabilize, allowing for detection of fluctuations in pressure due to normal breathing, which was approximately 2 mmHg for each inhalation and exhalation. Subjects were instructed to perform abdominal drawing in. The instructions were given to breathe in and out and then, without breathing in, to slowly draw in the abdomen so that it lifts up off the pad, keeping the spinal position steady. Deep inspiration was avoided. During this test, the investigator closely monitored the pressure gauge of the PBU and the subject to detect whether any compensatory mechanisms were employed, this included movements of the pelvis and spine, breathe holding, rib elevation and bulging of the abdomen. [12,13,14,17] Pressure reduction which was held at least up to 10 seconds was noted. Stop watch was used to note down the time. A sudden rise in pressure indicated fatigue. The same procedure was repeated for three times and the best of the three repetitions was used for analysis. Rest time between the measurements was 1 min.

STATISTICAL ANALYSIS

For the purpose of analysis subjects were divided into four groups based on age i.e. A = 18-30 years, B = 31-40 years, C = 41-50 years, D = 51-60 years. MedCalc for Windows, version 19.7.4 (MedCalc Software, Ostend, Belgium) was used for statistical analysis. Normality tests were done for all parameters using Shapiro wilk test. Data of pressure reduction on PBU was found to be skewed from normal distribution. Reference ranges were calculated with 90% CI. Reference ranges for core strength among subjects based on age and gender were calculated using mean, standard deviation, median and interquartile Range.

RESULT

TABLE 1: Descriptive statistics of subjects

		Age (years)	Height (cms.)	Weight (Kgs.)	BMI (Kg/mt^2)
A	M (n=395)	22.89 (2.73)	1.72 (0.05)	63.25 (6.79)	21.49 (2.08)
	F (n=48)	25.77 (3.05)	1.55 (0.06)	56.92 (11.13)	23.63 (4.37)
	Total (n=443)	23.20 (2.91)	1.70 (0.07)	62.56 (7.62)	21.72 (2.52)
B	M (n=67)	34.69 (2.95)	1.69 (0.06)	71.39 (12.70)	24.95 (4.25)
	F (n=65)	36.34 (2.87)	1.55 (0.05)	64.31 (11.97)	26.78 (4.63)
	Total (n=132)	35.50 (3.01)	1.62 (0.09)	67.90 (12.80)	25.85 (4.52)
C	M (n=47)	45.55 (3.17)	1.70 (0.06)	71.17 (10.41)	24.68 (3.17)
	F (n=91)	44.76 (2.61)	1.55 (0.06)	67.52 (10.21)	27.97 (4.19)
	Total (n=138)	45.03 (2.83)	1.60 (0.09)	68.76 (10.39)	26.85 (4.17)
D	M (n=51)	54.61 (2.81)	1.70 (0.06)	75.25 (11.45)	25.48 (3.82)
	F (n=79)	55.04 (3.02)	1.55 (0.05)	67.54 (10.89)	28.15 (4.22)
	Total (n=130)	54.87 (2.94)	1.61 (0.09)	69.78 (11.42)	27.10 (4.26)
Total	M (n=560)	29.09 (11.0)	1.71 (0.05)	65.80 (9.38)	22.53 (3.16)
	F (n=283)	42.47 (10.49)	1.55 (0.05)	64.99 (11.59)	27.01 (4.61)
	Total (n=843)	33.58 (12.54)	1.66 (0.09)	65.53 (10.18)	24.04 (4.27)

Mean (SD) is expressed for all parameters; Age groups (A=18-30 years, B=31-40 years, C=41-50 years, D=51-60 years); Gender (M=Male, F= Female); BMI -Body Mass Index; n – Total number of subjects

Table1 showed that the mean age of all subjects was 33.58 years with mean Body mass index (BMI) 24.04 kg/mt^2. Among all subjects, 560 subjects were male and 283 subjects were female. 443, 132, 138 and 130 subjects belong to group A, B, C and D respectively. Mean age was 23.20 years, 35.50 years, 45.03 years and 54.87 years for group A, B, C and D respectively.

TABLE 2: Reference range of core muscle strength

		A	B	C	D	Total		
						M	F	Total
Mean (SD)		9.01(1.44)	7.64(2.48)	6.31(2.56)	5.38(2.41)	8.62(1.96)	6.16(2.54)	7.79(2.46)
Percentile	25th	8	6	4	4	8	4	6
	50th	10	8	6	5	10	6	9
	75th	10	10	8	6	10	8	10
IQR		2	4	4	2	2	4	4
Lower limit	Value	5	2	2	2	5	2	2
	90% CI	3-5	2-3	2-2	2-2	3-5	2-2	2-3
Upper Limit	Value	10	10	10	9	10	10	10
	90% CI	10-10	10-10	10-10	8-10	10-10	10-10	10-10
Reference range		5-10	2-10	2-10	2-9	5-10	2-10	2-10

All values are expressed in mmHg; Age groups (A=18-30 years, B=31-40 years, C=41-50 years, D=51-60 years; Gender (M=Male, F= Female); SD – Standard Deviation; IQR – Interquartile Range; CI – Confidence Interval

Table 2 presents reference range for all subjects to be 2 – 10 mmHg with males having range 5 – 10 mmHg and females having range 2 – 10 mmHg. Reference range for group A was 5 – 10 mm Hg, for group B, C was 2 -10 mmHg respectively and for group D was 2 – 9 mmHg.

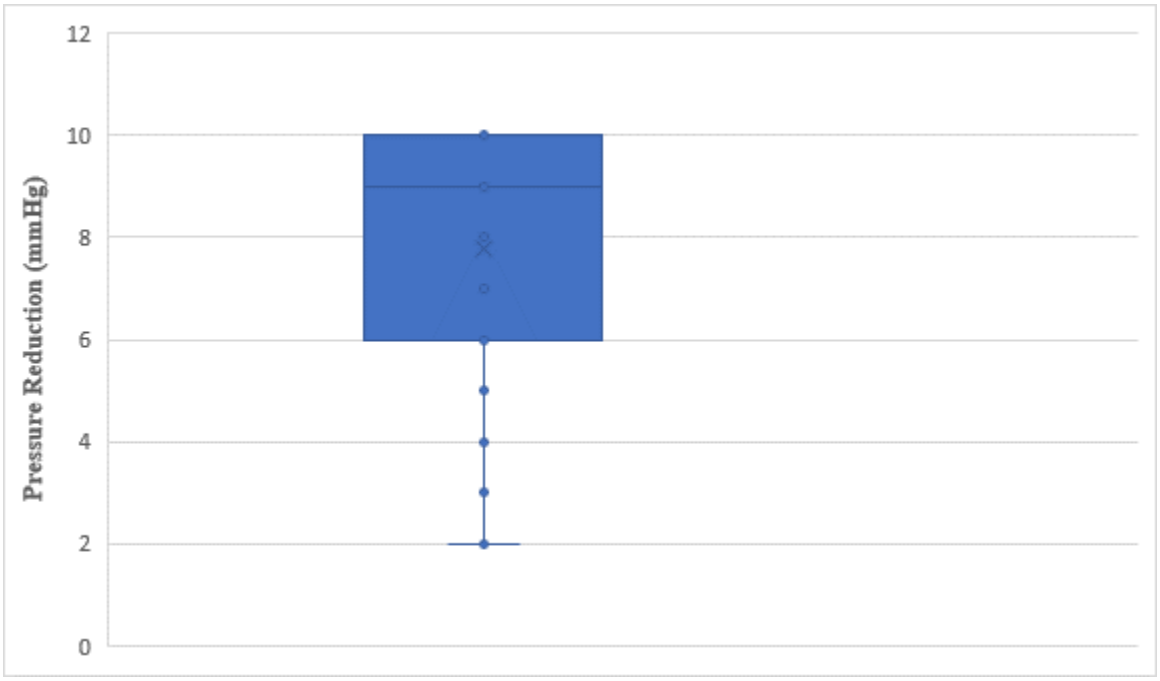

FIGURE 1: Box whisker graph for pressure reduction on PBU of all subjects

Figure 1, reference range of all subjects is shown to be 2 – 10 mmHg with median 9 mmHg.

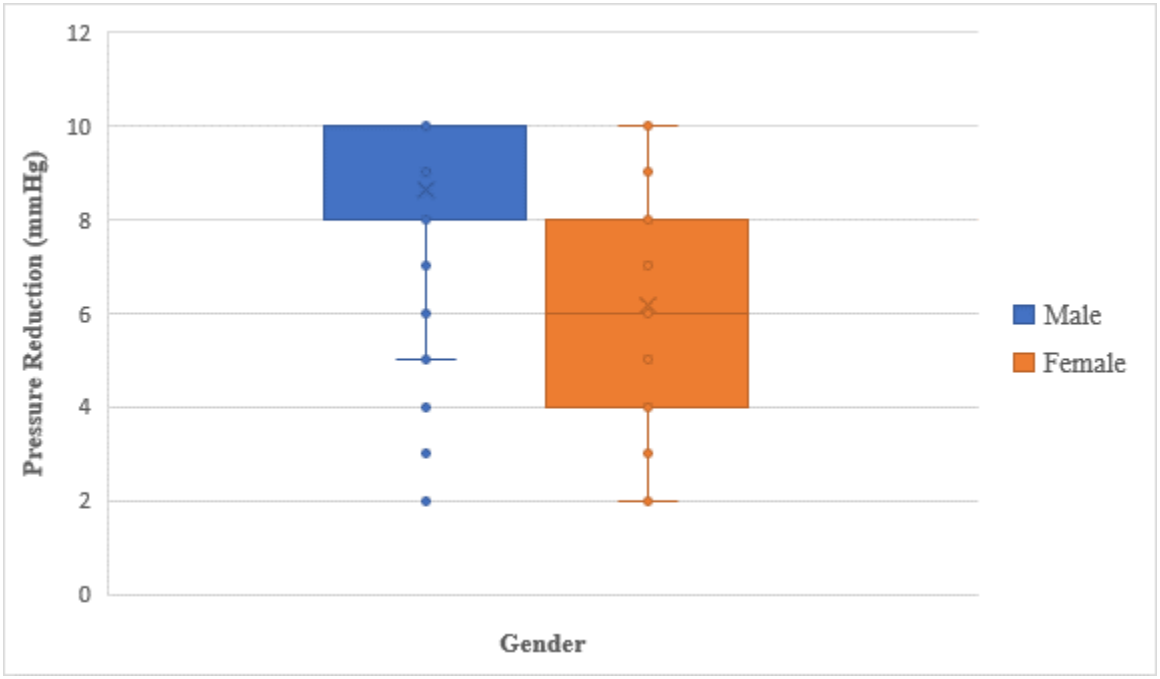

FIGURE 2: Box whisker graph for pressure reduction on PBU for all subjects based on gender

Figure 2 shows reference ranges of males to be higher than females with median 10 mmHg for males and 6 mmHg for females.

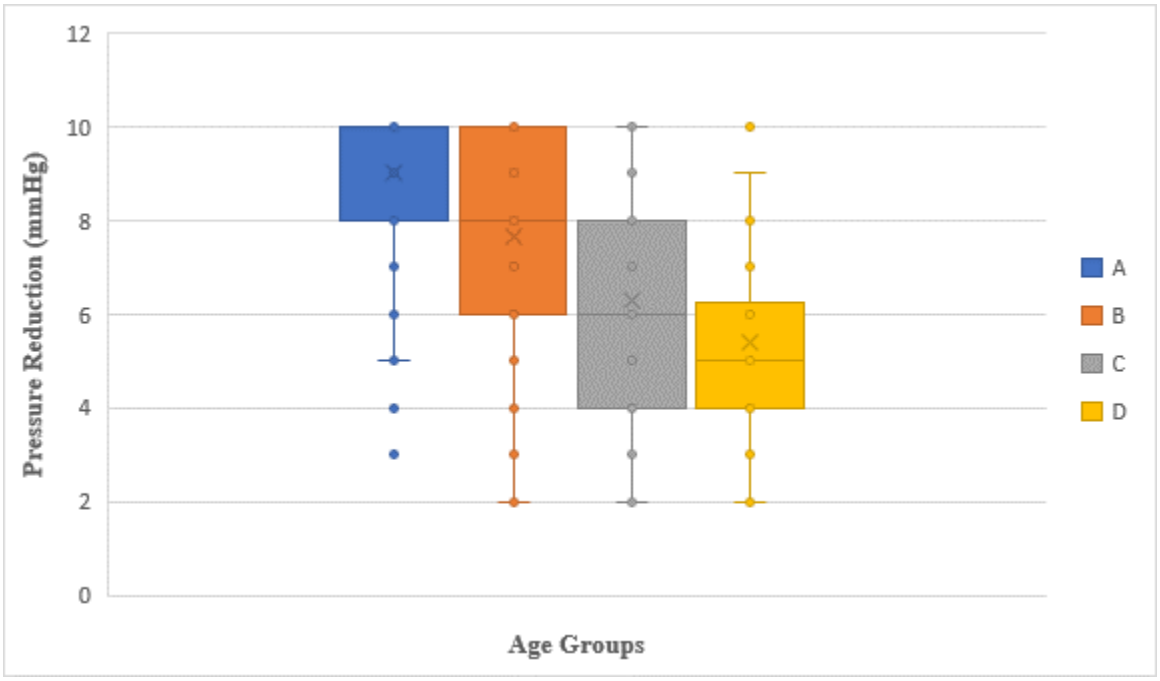

FIGURE 3: Box whisker graph showing reference ranges of pressure reduction on PBU in various age groups

Figure 3 depicts that the reference range for core muscle strength decreases with the age.

DISCUSSION

Strength of TrA signifies the core strength of the lumbar region as TrA is one of the local muscles of lumbar spine. Estimation of strength of TrA was done on the basis of amount of pressure reduction on PBU when the subject was in prone lying position. Analysis of core strength is done using median as a measure of central tendency as the data showed skewed distribution. PBU provides measurement markings in terms of 2, 4, 6, 8 and 10 mmHg. So, the marking in

between 2 and 4 mmHg was considered 3 mmHg and likewise. Further, it does not provide data in 1.5, 2.5 …9.5 mmHg. Moreover, when measuring core strength using PBU it is measured in terms of finite values i.e., 0,1,2, 3……. 10 mmHg which are a discrete data, as PBU does not provide measurement in continuous data.

The result of the study showed median score of pressure reduction on PBU to be 9 mmHg for all the subjects. Reference range was 2 – 10 mmHg for all the subjects between the age group of 18-60 years. This is in contrast to the range given by Hodges et al i.e., 6 – 10 mmHg and Richardson et al i.e.,4 – 10 mmHg. [8,18,19] There is lack of literature regarding nature of subjects in terms of age and gender enrolled for their study. Guidelines given by Richardson et al suggest pressure drop of less 2 mmHg to be abnormal.[19] None of the guidelines given by Richardson et al and Hodges et al states about pressure drop between 2 – 4 mmHg. [8,19] Our findings also suggest that these reference ranges differ by age and gender of the individual. If mean of pressure reduction on PBU is considered for analysis as most of the literature has mentioned, results of our study found mean pressure reduction to be 7.79 mmHg in 18 – 60 years of age group. In contrast, Cairns et al found mean pressure reduction of 3.30 mmHg in normal individuals.[8] But sample size of their study was very small i.e., 19 subjects between the age group of 16 – 75 years. Brilla et al has found mean pressure reduction of 9 mmHg in 10 healthy recreationally active individuals in age group of 18 – 25 years.[20] Thus, it can be stated that small sample size, different age groups and sample selection in various studies makes it difficult to compare results of our study. Reference range of 2 – 10 mmHg found from our study suggests that individuals below 2 mmHg are at risk of developing low back pain in future. Reduced performance on abdominal drawing in manoeuvre is thought to result in low back pain.[21] Luiz et al has found the pressure reduction of 1 – 2 mmHg in 29 patients having lumbar disk herniation consequently associated with low back pain.[22] Moreover, considering the guidelines given by Richardson et al subjects with pressure reduction between 2 – 3 mmHg may be at borderline risk of developing back pain in future even though they are asymptomatic at present.[19] Similarly, for guidelines given by Hodges et al, subjects having pressure reduction between 2– 5 mmHg may develop low back pain in future.[18] Further, a treatment goal and progression of treatment can be set for individuals based on the score achieved. In our study, Interquartile range (IQR) for all the subjects was 4 which suggests that 50% of the subjects were within the range of 6 – 10 mmHg. Reference ranges found from our study was 5 – 10 mmHg for group A, 2 – 10 mmHg for group B and group C respectively and 2 – 9 mmHg for group D. This shows young population have higher core strength in comparison to older population. According to guidelines of Richardson et al range 4 – 10 mmHg is considered normal.[19] Paul et al has also observed age related decline in TrA in response to arm abduction.[23] Elderly people showed slower activation of TrA compared to young adults. In contrast, Brilla et al found the pressure change between 5 - 15 mmHg among healthy, recreationally active individuals between age group 18-25 years, though the sample size was very small i.e., 32 individuals.[20] Ota et al concluded that age related decline in thickness of TrA is not significant. They stated that it was because as muscle mass of TrA is maintained by muscle mass of paraspinals, which acts to resist force of gravity during all daily living activities irrespective to age.[24] But this study was done on healthy, active women only between the age group of 20-85 years. Moreover, muscle thickness was measured by ultrasonography. Whereas in our study both the genders were analysed and methodological differences do exist such as we measured strength of deep muscles i.e., TrA with indirect method of measurement by PBU. In our study gender difference was

found among all subjects between age group of 18 – 60 years. This difference may exist due to physiological/morphological difference between the two genders. Reference range for males was 5 -10 mmHg whereas for females was 2 – 10 mmHg between the age group of 18-60 years. Males have larger muscle cross-sectional area of trunk muscles compared to females which could be responsible for the strength differences. Another reason for this gender difference can be body fat mass which is found to be more in females compared to males. Our findings are consistent with the finding of Rho et al found a gender difference during abdominal drawing in manoeuvre as male had 0.71 cms and female had 0.61 cms thickness measured on ultrasound imaging.[25] Similar findings were found for thickness of TrA during abdominal drawing in manoeuvre using ultrasound imaging between both genders by Manshadi et al.[26] On the contrary, Paul et al found no gender difference in performance of TrA.[23] This may be different from our findings as they analysed only men in the young group and in the older group men and women both were analysed, sample size was very small compared to our study. Santosh M et al found females (2.1) having more core muscle activation compared to males (1.7).[27] They recruited young adult subjects with BMI $\geq$ 24 kg/mt^2 having low back pain. They had recruited a greater number of females compared to males. They assessed core muscle activation with Sahrmann core stability test. As the subjects with low back pain were recruited for the above study, this may alter the findings as due to low back pain activation of core muscles is altered which is in contrast to our study where only normal subjects were recruited. In contrast to above study our method for core strength assessment was different and further we have assessed subjects from various age groups.

Limitations of our study include that history of low back pain was asked subjectively in form of yes or no. This could have affected our results as low back pain can hamper the function of TrA. Marking on the PBU is in even numbers and odd numbers are not mentioned on it so the assessor may be biased to note down only even numbers. PBU is found to less valid tool for accurate results but it may be clinically helpful. Position of prone lying may be uncomfortable to obese individuals. Endurance of core muscles was not assessed. When subjects were classified further on the basis of gender, sample size reduced making it difficult to interpret the range.

In future study can be done with more sophisticated instrument such as fine wire EMG and real time ultrasonography that can be used to assess core strength, more groups can be used based on BMI, WHR and physical activity.

CONCLUSION

Thus, it can be concluded that the reference range for strength of Transversus Abdominis is 2 – 10 mmHg in normal individuals. Reference range varies according to age and gender of the person.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: Authors are thankful to all the participants for making the work possible.

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Sheshna R. Rathod, Neeta J. Vyas, Dinesh M. Sorani. Evaluating core muscle strength for transversus abdominis among normal individuals - an observational study. *Int J Health Sci Res.* 2023; 13(10):38-46. DOI: *https://doi.org/10.52403/ijhsr.20231005*

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