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Co-relationships between core endurance, hip strength and balance in athletes

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Abstract
Background: In Athletics, running is the most effective way to improve cardiopulmonary endurance and overall health. But simultaneously it is also associated with high-risk musculoskeletal injuries. Nearly 50 % of injuries in regular runners are because of overuse and the prevalence of lumbar spine and lower limb injuries is higher in the athletic population. Most of the common injuries are associated with poor core endurance, altered biomechanics, and lack of proper trunk and lower extremity muscle strength. Core muscle endurance, lower extremity musculature strengthening, and neuromuscular control are commonly used to enhance athletic performance. However, based on the literature review, the precise impact of back core muscle endurance, hip muscle strength, and balance is still not clear. So, the purpose of this study was to find out the relationship between core endurance, hip strength, and balance in athletes, as well as to find out the normative data for trunk core endurance, hip muscle strength, and balance in athletes.
Method: After obtaining ethical approval from the institutional ethical committee and informed concern, 187 healthy long-distance runners, including 136 males and 51 females, between the age group of 18 to 35 with a Mean age is 27.07+4.52 for Males and 25.94+4.13 for females included this study. Core endurance (Anterior, posterior, and lateral) was measured using Mcgill's endurance test, hip muscle (flexors, extensors, and abductors) strength was measured using an MMT handheld dynamometer, and balance was measured using a star excursion balance test.
Data Analysis and Result: All statistical Data analysis was done using SPSS version 21.0 at an alpha level of 0.05. Pearson product correlation was used to examine the relationship between core endurance, hip strength, and balance. A linear regression analysis was used to check the influence of core endurance and hip strength on balance.
Conclusion: Trunk core endurance was fairly correlated with hip flexors, extensors, and abductors muscle strength. There was a Fair positive correlation existed between anterior, posterior, left, and right lateral core endurance and SEBT com score. There was a strong correlation between hip flexor strength and balance bilaterally. This conclusion implies that when the hip flexors (e.g., the quadriceps) are stronger, an individual may reach further forward. And there was a fair correlation between hip extensors, abductors, and balance. This study also established normative data for trunk core endurance, hip muscle strength, and balance.

Keywords: Core endurance, hip strength, balance, athletes, normative values

Introduction
According to the Oxford English dictionary, Athlete is a person who, take part in competitive running, jumping, throwing, and walking activity. The most common athletics activities are track & field, road running, and cross-country running [1]. Running is one of the effective ways to improve overall health and so it is the most popular sport worldwide, but it is also associated with high-risk injuries [2].
Musculoskeletal injuries are most common in runners [3, 4]. Nearly 50 % of regular runners reported more than one musculoskeletal injury each year [2]. Some musculoskeletal injuries are accidental but most of the injuries are caused by overuse [2]. The Lumbar spine and lower extremities are the most common injuries among athletic Populations [2, 3, 4]. Most of the injuries are commonly associated with weakness, poor endurance, and lack of proper trunk and hip strength [5, 6, 7]. Various researchers have identified several risk factors such as lack of core strength, proximal hip muscle weakness, and lower extremity proprioception/balance deficits for the increased incidence of Lower extremity Injuries [8].

Furthermore, core stability (CS) is necessary to provide a stable base for lower kinetic chain motion [8]. The link between CS and the lower extremity has been recognized as a possible cause of functional instability in the lower extremity as a whole [8, 9]. Researchers also found that decreased core proprioception and neuromuscular control a predictors of knee injury risk in athletes [10]. In Professional athletes, Trunk muscular endurance testing is commonly used to identify athletes who may be at risk of muscle injuries, evaluate rehabilitation outcomes, and improve athlete performance [13]. However, the precise impact of back core muscular endurance and hip muscle strength on balance is still unknown. Furthermore, there is limited normative data available for trunk muscle endurance in the literature, particularly in India. the specific links between core endurance, hip strength, and balance, as well as how they interact in athletes, are unknown, and a lack of normative data limits the measurement of spinal physical functions like Range of motion, strength, endurance, and balance. So, the purpose of this study was to observe the relationship between core endurance, hip strength, and balance in athletes, as well as to find out the normative data for trunk endurance, hip strength, and balance in athletes.

Materials and Methodology

Cross-sectional observational study. After obtaining Ethical approval from the Institutional Ethics Committee. Data were collected from various sports grounds in Vadodara. A convenient sampling method was used. Total sample size: 187 based on the previous study [14]. The duration of the study was 5 years. Athletes were selected based on the Inclusion of Healthy Males and Females, Age group 18 to 35 Years, athletes who regularly run 15 km or more distance per week, and participated at least 2 times last year in a Running competition (10 km or 21 km or 42 km) and exclusion criteria was Any Previous lower limb, upper limb or spine fracture or major surgery in last 6 months, Lower extremity injury in the past 6 Months, Any neurological or musculoskeletal conditions affecting mobility or Balance, any cardiopulmonary disorders, Hernia. Outcome Measures Core endurance was assessed with McGill's endurance test [14], Isometric hip strength was assessed by MMT handheld dynamometer [15], and Balance was examined by SEBT (lower quarter) [33]. Measurement of core endurance by McGill's Endurance Tests Overall Intra-rater reliability is moderate to very high (ICC 0.66 – 0.96).92. McGill's core endurance tests were utilized to assess participants' core endurance, which consisted of four positions: 1) trunk anterior flexor test, 2) trunk posterior extensor test, 3) right lateral plank, and 4) left lateral plank. Participants completed one practice trial and one actual test trial for each position, during which the maximum time (seconds) they could hold a static position was measured. (Nesser *et al*. 2008) [12]. The investigator verbally used the words 'start' and 'stop' to inform the participant to begin and end the test and recorded the times using a stopwatch.5 minutes rest between each test was given. (Nesser *et al*. 2008) [12]. Hip muscle strength measurement using MMT handheld dynamometer. Hip strength assessment plays an important role in the clinical examination of the hip and groin region. Adequate hip muscle performance is required to control the alignment of the lower extremity. Test-retest reliability is good to excellent (ICC 0.86-0.97) [24, 25].

Hip isometric strength of hip flexors, hip extensors, and hip abductors was assessed bilaterally by using an MMT handheld dynamometer. A total of 3 trials and 1 practice trial were given to all participants and an average score of three trials was considered as a final score 10-second rest time was given between trials and all testing was done on the left leg first, then the right. Maximum strength data was recorded in kilograms. Balance examination using Star Excursion Balance Test (SEBT) (Lower Quarter) SEBT was used to assess dynamic balance and core control in athletes. Intrarater reliability of SEBT is excellent. According to Phillip *et al*., it is ICC 0.86 to 0.92; according to Hertel *et al*. it is ICC 0.85 - 0.96 and according to plisky reliability of SEBT ranges between ICC 0.82-0.87 [19, 24].

All participants were taught how to perform the test by using both verbal instruction and demonstration. Before performing the test, limb length was measured using measure tape from ASIS to medial malleolus.

Participants were allowed 3 practice trials in each direction before the actual test performance. A participant stands on one foot in the center of the line with both hands on the waist. Then, with a single-leg stance participants performed a maximal reach of the opposite leg along marked lines while keeping the stance leg placed stable at the center, and then returned to the initial upright posture without losing balance. Participants performed anterior, posterolateral, and posteromedial reach.

The investigator marked the spot on the line where the participants were able to reach. The test was repeated 3 times for each side. All the participants tried to reach out with their right leg first, then their left leg. The reaches were performed in the following order: anterior, posteromedial, and then posterolateral. Between each trial on the same leg and in the same direction, participants got a 15-second rest interval, and a 1-minute rest interval between reaches in other directions and when changing foot. If the participant was unable to maintain a single leg stance, (2) the heel of the stance foot did not remain in contact with the floor, (3) weight was moved onto the reaching foot, or (4) the start and return postures were not maintained for one full second, the trial was disregarded and restarted. final score was calculated by average distance in each direction/leg length *100. Overall, 6 different SEBT scores were calculated: 3 directional scores on the right leg and 3 directional scores on the left leg. Lastly, all 6 SEBTs were averaged to result in a single composite SEBT score per participant.

Result and Analysis

All statistical Data analysis was done using SPSS version 21.0 at an alpha level of 0.05. Pearson product correlation was used to examine the relationship between core endurance, hip strength, and balance. A linear regression analysis was used to check the influence of core endurance and hip strength on balance.

Table 1: Characteristics of Athletes

Parameter	Male	Female	(Mean ± SD)
Frequency	136 (72.7%)	51 (27.3%)	---
Age (years)	27.2 ± 4.5	25.7 ± 4.1	26.8 ± 4.4
Height (cm)	167.1 ± 6.1	160 ± 6.0	163.5 ± 6.1
Weight (kg)	67.2 ± 6.1	57.0 ± 0.2	62.0 ± 3.2
BMI (kg/m^2)	24.0 ± 0.5	22.3 ± 0.8	23.2 ± 0.7

Table 2: Back core endurance scores, hip strength and star excursion balance test (SEBT) scores (Means ± SD)

Test	Side	Direction	Mean	SD
Core Endurance	-	Trunk Flexor (Anterior)	100.62	±51.92
		Trunk Extensor (Posterior)	84.85	±24.77
		Rt lat. Plank	68.88	±21.28
		Lt lat. Plank	68.09	±20.71
Hip Strength	Right	Flexors	14.68	±3.16
		Extensor	14.33	±2.84
		Abductors	11.88	±2.16
	Left	Flexors	14.40	±2.93
		Extensors	14.16	±3.05
		Abductors	11.68	±2.25
SEBT	Right		118.27	±9.71
	Left		117.90	± 9.75
	Composite Score ($SEBT_{COM}$)		118.04	±9.52

Table 3: Pearson correlations between core endurance (Mcgill's test scores (s)) and balance ($SEBT_{COM}$)

Core Endurance (McGill's Test)					
		Anterior	**Posterior**	**Plank- RT**	**Plank -LT**
$SEBT_{COM}$	r	0.227	0.413	0.448	0.436
	p	0.002	<0.0001	<0.0001	<0.0001

r: Correlation coefficient, p: probability
*Correlation is significant at the 0.01 level (2-tailed)

Table 4: Pearson correlations among balance ($SEBT._{COM}$) and hip strength (KG)

		H_{FL-RT}	**H_{FL-LT}**	**H_{EXT-RT}**	**H_{EXT-LT}**	**H_{ABD-RT}**	**H_{ABD-LT}**
$SEBT_{COM}$	r	0.425	0.486	0.413	0.347	0.418	0.380
	p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

r: Correlation coefficient, p: probability
*Correlation is significant at the 0.01 level (2-tailed)

Table 5: Pearson correlations among core endurance (Mcgill Test (S)) and hip strength (KG)

Core Endurance (McGill's Test)					
Hip strength	**Value**	**Anterior**	**Posterior**	**Plank- RT**	**Plank -LT**
H_{FL-RT}	r	0.606	0.553	0.611	0.557
	p	<0.0001	<0.0001	<0.0001	<0.0001
H_{FL-LT}	r	0.529	0.525	0.612	0.588
	p	<0.0001	<0.0001	<0.0001	<0.0001
H_{EXT-RT}	r	0.367	0.487	0.541	0.818
	p	<0.0001	<0.0001	<0.0001	<0.0001
H_{EXT-LT}	r	0.281	0.388	0.498	0.480
	p	0.0003	<0.0001	<0.0001	<0.0001
H_{ABD-RT}	r	0.475	0.484	0.536	0.581
	p	<0.0001	<0.0001	<0.0001	<0.0001
H_{ABD-LT}	r	0.412	0.408	0.476	0.512
	p	<0.0001	<0.0001	0.0296	<0.0001

r: Correlation coefficient, p: probability
*Correlation is significant at the 0.01 level (2-tailed)

Table 6: Normative percentile data for core endurance and balance

Test	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
Core Endurance (Sec.)-Anterior	44	71.00	87.00	110.00	300
Core Endurance (Sec.)-Posterior	30	68.00	83.00	101.00	168
Core Endurance (Sec.) Rt Lateral	19	54.00	72.00	84.00	130
Core Endurance (Sec.) Lt Lateral	24	52.00	70.00	81.00	140
Balance (SEBT) % RT	95	113.00	119.00	124.00	150
Balance (SEBT) % LT	92	113.00	119.00	124.00	156

Table 7: Normative percentile data for hip strength

Test	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
Hip Muscle Strength (Kg) Flexors Rt	9	12.00	15.00	17.00	30
Hip Muscle Strength (Kg) Flexors Lt	9	12.00	15.00	16.00	28
Hip Muscle Strength (Kg) Extensors Rt	9	12.00	15.00	16.00	21
Hip Muscle Strength (Kg) Extensors Lt	8	12.00	15.00	16.00	21
Hip Muscle Strength (Kg) Abductors Rt	7	10.00	12.00	13.00	17
Hip Muscle Strength (Kg) Abductors Lt	7	10.00	12.00	13.00	21

Table 8: Test for significance of Difference between core endurance and balance Anova

Sr. No.	Model	Sum of Squares	Df	Mean Square	F	p-Value
1	Regression	4056.945	4	1014.236	14.429	.000[b]
	Residual	12792.712	182	70.290		
	Total	16849.658	186			

Variable a. Balance (SEBT)
Variable b. Core Endurance (Second) Plank Lt, Core Endurance (Second)-Anterior, Core Endurance (Second)-Posterior, Core Endurance (Second) Plank Rt

Table 9: Test for the significance of difference between balance and hip strength Anova

Sr. No.	Model	Sum of Squares	Df	Mean Square	F	p-Value
1	Regression	4698.826	6	783.138	11.601	.000[b]
	Residual	12150.832	180	67.505		
	Total	16849.658	186	---		

Variable a. Balance (SEBT)
Variable b. Hip Muscle Strength (Kg) Abductors Lt, Hip Muscle Strength (Kg) Flexors Rt, Hip Muscle Strength (Kg) Extensors Lt, Hip Muscle Strength (Kg) Abductors Rt, Hip Muscle Strength (Kg) Extensors Rt, Hip Muscle Strength (Kg) Flexors Lt.

Discussion

The main objective of the study was to find out the correlation between back core endurance, hip strength, and balance in athletes and the secondary objective was to develop normative data for core endurance, hip muscle strength, and balance. In this study, 187 healthy long-distance runners, including 136 males and 51 females were between the age group of 18 to35 with a Mean age is 27.2+4.52 for Males and 25.7+4.13 for females as shown in Table 1.

1. Core endurance and hip strength

Table 2 shows mean data for core endurance, which was 100.62, 84.85, 68.88, and 68.09 for trunk flexors, extensors, and right &; left lateral flexors respectively. Hip muscle strength was 14.68, 14.33, and 11.88 for right hip flexors, extensors, and abductors respectively and 14.40, 14.16 and 11.68 was for left hip flexors, extensors and abductors respectively. As per shown in table 5 core endurance was fairly corelated with hip flexors, extensors, and abductors muscle strength. The hamstrings, quadriceps, and iliopsoas muscles attach to the same anatomical locations as the core musculature (e.g., the ilium, ischium, and pubic bones), leading clinicians to conclude that the lower back endurance may be influenced by hip extensors muscles.

Although there was a link between hip flexors, extensors, and abductors and SEBT scores, these hip muscles were only assessed in an isometric motion rather than during a dynamic exercise. Future studies could use dynamic hip strength tests (such as isotonic or isokinetic testing) to assess hip musculature and its relationship to balance measurements.

2. Core endurance and balance

As shown in Table 3, a Fair positive correlation existed between anterior, posterior, left, and right lateral core endurance and SEBT com score. This finding suggests that during dynamic lower extremity balance, the core should be active bilaterally. A core endurance training program looks to have the ability to improve balance. Gordon and colleagues also discovered no link between core endurance (as measured by the Bent Knee Lowering Test) and balance (as measured by the SEBT) [19]. Shirley *et al*. looked at core muscle activation during single-leg squats and found that individuals who consciously used their core muscles had better frontal plane hip and knee kinematics than those who did not [22]. It's possible that the differences between this previous research and the current findings are related to different tasks [22]. Overall, when previous findings are combined with the findings of this study, it appears that more research is needed to understand whether core musculature endurance and SEBT performance are related.

3. Co-Relation of Hip Strength and Balance

In this study, isometric hip flexors, extensors, and abductor, muscle strength were measured because these muscles have been shown to be active during the SEBT directional reaches. While muscle activation does not directly indicate muscle strength, the two measures are associated. Isometric strength measure of the flexors, extensors, and abductors demonstrated positive correlations with SEBT scores. Individuals with higher hip strength scores had higher total SEBT scores in general. Female basketball players with lower SEBT composite scores (less than 94 percent of limb length) were 6.5 times more likely to have a lower extremity injury than those with higher SEBT scores, according to the previous study [19]. SEBT scores improved 11-36 percent after 2-4 weeks of neuromuscular balance training, according to Rasool *et al*. [20]. When compared to typical rehabilitation, hip strengthening activities have been shown to enhance sagittal plane dynamic balance (anterior reach on the Y-balance test) three months after ACL surgery. 42 Similarly, A lower extremity strengthening and core stability Programme improved SEBT results in soccer players, according to Filipa *et al*. [21]The recent findings of increased hip strength being associated with improved SEBT performance are essential for clinicians to examine since they can use this information to urge female athletes to participate in hip strengthening and balance training programs. As shown in table 4 SEBT (cm) Scores was positively correlated with hip flexors strength bilaterally. This conclusion implies that when the hip flexors (e.g., Iliopsoas and the quadriceps) are stronger, an individual may reach further forward. Earl *et al*. showed that activation of the vastus medialis and vastus medialis obliquus (both quadriceps muscles) was higher in anterior excursions than in other SEBT directions. The authors are reasonably certain that these muscle activations represent overall quadriceps muscle activity patterns during SEBT anterior reaches, even though neither of these quadriceps muscle components cross the hip joint. SEBT (com) Scores were also fairly positively correlated bilaterally with hip extensor strength. This finding suggests that the hip extensors are significant and necessary for controlling the pelvis and trunk while maintaining balance during anterior reaches. SEBT (com) scores were fairly

positively correlated with hip abductors bilaterally. Individuals with stronger hip abductors, flexors, and extensors may be able to reach further backward and laterally without losing balance, according to these studies. Backpedaling is a common activity in sports that require the athlete to backpedal (e.g., basketball or lacrosse or soccer player defending the net or goals respectively). As a result, posterolateral SEBT scores may be a useful general indicator of hip muscle strength that clinicians can utilize to assess athletes; functional performance and progress during training and rehabilitation.

According to Portney and Watkins, if the strength of the relationships is 0.00- 0.25 it's considered as there is little or no relationship; if it is 0.26-0.50 then fair degree of relationship; if it is 0.51-0.75 then moderate to a good relationship, and 0.76-1.00 then there is good to the excellent relationship [18]. As per Table No. 3, 4, and 5 'p' Value less than 0.05, the null hypothesis is rejected and the alternative hypothesis 'There are significant correlations between core endurance, hip strength, and balance in the athlete' is accepted.

4. Normative data of core endurance, hip strength, and balance

There are very few studies done to find a normative database on core endurance (Trunk flexors, trunk extensors, and lateral flexors) muscle endurance in special healthy individuals and athletes [8, 9, 11, 12]. A study was done by Mbada *et al*. (2010) [13] on normative values of static and dynamic abdominal muscle endurance in healthy Nigerians shows a mean value of 34.9 sec for static endurance and 15.6 rep for dynamic endurance. McIntosh *et al*. 35 did a study on the trunk and lower extremity muscle endurance: They concluded that normative data for adults age group 19-29 years, who had endurance more than 75th percentile was 25% of males and females for dynamic chest raise, 18% male and 14% female for bilateral straight leg raise, 68% male and 62% female for static chest raise, 47% male and 46% female for prone bilateral straight leg raise. Identifying high or low muscular endurance can alert the patient and clinician to a need for possible modifications to the usual treatment regime [17]. The clinician uses many of the tests of the Canadian standardized test of fitness, but consideration has been given to the issue of reliability. In other studies, Mclntosh *et al*. [16] the reliability of several tests was assessed and reported. Isometric upper abdominals (r=0.63) and isometric lower abdominals (r=0.67) have fair to good test-retest reliability, while dynamic upper abdominals (r=0.87) and isometric lower back extensors (r=0.81) have excellent reliability.

In the present study, the normative data for core endurance, hip strength and balance has been reported. Poor endurance was defined as time spent holding a position less than the 25th percentile, medium endurance as time spent holding a position between the 25th and 75th percentile, and high endurance as time spent keeping a position longer than the 75th percentile. 34 The percentile value shown in the table suggests that core endurance less than 71, 68, 54, and 52 secs were considered as poor endurance for the Anterior, posterior, right, and left plank, respectively. Less than 12,12,10 kgs were considered as poor hip strength for flexors, extensors, and abductors, respectively. Less than 113 cm is considered a poor distance for balance. As per Table 5.6, 71-110, 68-101, 54-84, and 52-81 secs were considered as medium endurance for the Anterior, posterior, right, and left plank, respectively. 12-17, 12-16, and 10-13 kgs were considered as medium hip strength for flexors, extensors, and abductors, respectively. 113-124 cm is considered as a medium distance for balance. As Shown in Table 6, 110-300, 101-168, 84-130, and 81-140 secs were considered as good endurance for the Anterior, posterior, right, and left plank, respectively.17-30, 16-21, and 13-21 kgs were considered as good hip strength for flexors, extensors, and abductors, respectively. 124-156 cm is considered a good distance for balance.

5. Effect of core endurance and hip strength on balance

ANOVA Analysis shown in Table 7 suggests core endurance i.e., Anterior, Posterior, and Lateral significantly (0.05) influences the balance, and balance may be altered with approx. 14 seconds (F=14.429) change in the core endurance. A similar study was done by Ambegaonkar *et al*. 30 but they found there is no correlation between core endurance and balance.

ANOVA Table 5.8 shows an analysis between hip strength and balance. It suggests that hip muscle strength may influence the balance significantly and balance may be altered with approximately 11 kg (F=11.6) change in strength. Similarly, Ambegaonkar *et al*. [14] found that Fair positive correlation between anterior balance and hip flexors & extensors strength, a Fair positive correlation between posterolateral SEBT score with hip abductors and extensor strength, and a Positive correlation between hip extensors muscle strength and core endurance. Core muscle works as an anatomical base for the movement of distal extremities. Most of the prime movers' muscles and stabilizing muscles that provide distal movements are attached to the pelvis and spine which could be the possible reason for the stability, mobility, and balance of the lumbopelvic region during physical activity like running. Any changes in muscle strength, and endurance may lead to insufficient motor control, which may lead to increased chances of injuries [14].

Conclusion

This study concludes that Trunk core endurance was fairly correlated with hip flexors, extensors, and abductors muscle strength. There was a Fair positive correlation existed between anterior, posterior, left, and right lateral core endurance and SEBT com score. There was a strong correlation with hip flexor strength and balance bilaterally. This conclusion implies that when the hip flexors are stronger, an individual may reach further forward. And there was a fair correlation between hip extensors, abductors, and balance. This study also established normative data for trunk core endurance, hip muscle strength, and balance. This correlation and normative data can be helpful as a reference for the rehabilitation of athletes as well as in the prevention of injuries of the lower back, and hip and as an outcome measure for quantitative improvement and future research purposes.

Limitations

Relatively less female (n:51) participation and age range (18-35 years) decreases the generalizability of this study.

- Unequal distribution of male and female participants.
- Participants of this study were taken from one region only i.e., Vadodara.

- In addition to the hip muscles, the knee and various other lower leg muscles are involved in balance which was not assessed in this study.
- Randomization of the sequences for testing the core endurance, hip strength, and balance was not done, which may affect the result of the study.

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