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KINETIC AND KINEMATIC ANALYSIS OF LOCOMOTION SPEED OF HIGHER SECONDARY BOYS

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Abstract:

The purpose was to analyze selected components of locomotion speed. Thirty school boys of age ranging from 17 to 19 year were selected as subject. Selected anthropometric and mechanical parameters were body weight, body height, leg length, maximum locomotion speed, leg power, stride length, stride frequency, body inclination, angle of leg placement in braking phase, push-off angle, horizontal projection of CG in braking phase, horizontal projection of CG in propulsion phase, horizontal velocity of CG in braking phase, horizontal velocity of CG in propulsion phase, velocity of swing leg in braking phase, velocity of swing leg in propulsion phase, angular velocity of thigh in propulsion phase, contact phase, flight phase, braking phase, and propulsion phase. The maximum locomotion speed was determined by a field test. Running action was filmed by a digital video camera with 120 fps for the distance between 40 to 50 m of the 100 m race. The anthropometric parameters were measured using standard procedure. The selected mechanical parameters were analyzed by motion analysis software. Results showed that weight, height, leg length, stride length, stride frequency had higher positive correlation with maximum locomotion velocity, whereas, contact phase, flight phase and propulsion phase had higher negative correlation with maximum locomotion velocity.

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1.0 INTRODUCTION:

Running, undoubtedly secures its unique place among classical athletic sports (Lindhard, 1939). It includes both proportions - simple as well as difficult. When it is instinctive and natural, it is simple; whereas it can be coined difficult due to its mechanical complexity (Dyson, 1986). Running earns a place as one of the most important components of movement structures in most of the games and sports. In our busy daily life, we need to run a little bit. Therefore, both for the athletes and the non-athletes, efficiency in running is fundamentally important.

There are certain factors that influence running. Two separate individual athletes never run exactly in the same manner; though, the basic sprinting mechanical principles should remain the same for all.

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In recent times, researchers have been toiling to analyze several aspects of running technique in terms of mechanics. Some of them are arm action, body lean, foot contact, over striding, under striding etc. There are many variables that influence running performance. According to the studies of Mero and Komi (1987), Bruggeman and Glad (1990), Mero, Komi and Gregor (1992), Mero and Komi (1994), Tidow and Wiemann (1994), the most important factors are: start reaction time, technique, production of force, neural factors and some external factors like running surface, footwear, and weather conditions. The efficiency of running velocity depends on an optimal cooperation of four phases: starting phase, acceleration phase, maintenance phase, and deceleration phase (Mero, Komi & Gregor, 1992). Maximal velocity, defined as the product of the stride length and stride rate, is without a doubt, one of the most important factors of running speed. Stride length and stride rate are interrelated and dependent on morphologic characteristics, duration of contact phase, force production in the braking and the propulsion phases.

Thirty years of valuable research works, attempting to evaluate the factors responsible for running are available to us. On the other hand, there are so many assumptions and speculations that hinder our way of understanding of definite responsible factors behind human running performance. More research is required to know the responsible factors exactly and their specific influence on running performance. In addition, there is dearth of knowledge related to mechanical analysis of running performance in Indian subcontinent and in the state of West Bengal as well.

Present study was an attempt, undertaken to perceive the accountable factors behind the running performance and their degree of influence on 17-19 year old boys as they are on the verge of attaining physical maturation.

2.0 METHODOLOGY:

As per the nature of the study, schoolboys of age group from 17 -19 year were selected as the subject. The group consisted of thirty (n = 30) subjects from the district Nadia of the state of West Bengal. The subjects had no previous experience of scientific training.

The selected anthropometric variables were (i) body weight, (ii) body height, and (iii) leg length. The selected mechanical variables were (i) maximum locomotion velocity, (ii) leg power, (iii) stride length, (iv) stride frequency, (v) body inclination, (vi) angle of leg placement in braking phase, (vii) push-off angle, (viii) horizontal projection of CG in braking phase, (ix) horizontal projection of CG in propulsion phase, (x) horizontal velocity of CG in braking phase, (xi) horizontal velocity of CG in propulsion phase, (xii) velocity of swing leg in braking phase (touch down), (xiii) velocity of swing leg in propulsion phase, (xiv) angular velocity of thigh in propulsion phase, (xv) contact phase, (xvi) flight phase, (xvii) braking phase (touch down), and (xviii) propulsion phase.

All the aforesaid variables were assumed to be influential for the prediction of maximum locomotion speed. The selection of variables was similar to a great extent with the study conducted by Murphy et al (2003). Some additional variables were also considered in accordance with the nature of the performance. Here maximum locomotion velocity was considered as dependent variable and the others were considered as independent variables.

The running movement of the subject was captured following scientific principles of videography for kinematic analysis. The camera (Casio exilim ZR100) was placed at a distance of 10 m from the subject in case of 100 m dash. The height of the camera was fixed at 1 m from the ground. The camera frequency was fixed with 120 fps. The camera optical axis was perpendicular to the direction of movement.

Prior to capture video, colored magnetic markers were attached at different points of interest of the body parts of the subjects such as ankle joint, knee joint, elbow joint, wrist joint etc. Firstly, all the subjects were asked to run 100 m distance on a running track. The running action at a distance between 40 m to 50 m from the start was recorded for stride frequency.

The total time taken by the subject was measured by a manually operated digital stopwatch capable of measuring one-hundredth part of second. The anthropometric parameters were measured following standard procedures.

The selected parameters of running with top locomotion speed were analyzed by Silicon Coach and Kinovea motion analysis software to yield numeric data. After that the numeric data were analyzed statistically through SPSS ver. 19 to get results and to draw conclusions.

The mean values and standard deviations of all the parameters were calculated. Then correlation between maximum velocity and other independent variables was calculated to find the degree of relationship. Regression equations were also developed with maximum velocity as dependent variable and the rest of the parameters as the independent variables. PCA test was done to remove multi co-linearity effect. And factor analysis was also done to explain the variables in terms of their common underlying dimensions.

3.0 RESULTS AND DISCUSSION:

Table 1 shows the mean values and SD of dependent and independent variables for running performance of higher secondary school boys.

Table 1: Mean and SD of independent and dependent variables

Sl. No.	Name of the variable	Mean	SD (±)
1.	Max. velocity(m/s)	7.25	0.70
2.	Weight (kg)	59.16	8.23
3.	Height (m)	1.67	0.07
4.	Leg length (m)	0.96	0.07
5.	Leg power (m)	0.45	0.07
6.	St. length (m)	1.78	0.16
7.	St. frequency (st/sec)	4.07	0.29
8.	Body inclination (deg)	9.94	3.73
9.	Angle of leg placement in braking phase (touch down) (deg)	65.93	4.42
10.	Push-off angle (deg)	64.70	4.11
11.	Horizontal projection of CG in braking phase (touch down) (m)	0.39	0.08
12.	Horizontal projection of CG in propulsion phase (m)	0.42	0.08
13.	Horizontal velocity of CG in braking phase (touch down) (m/s)	5.76	1.61
14.	Horizontal velocity of CG in propulsion phase (m/s)	5.42	1.17
15.	Velocity of swinging leg in braking phase (touch down) (m/s)	6.74	2.40
16.	Velocity of swinging leg in propulsion phase (m/s)	9.80	1.62
17.	Angular velocity of thigh in propulsion phase (deg/sec)	429.1	121.7
18.	Contact phase (ms)	152.00	19.37
19.	Flight phase (ms)	94.67	19.61
20.	Braking phase (touch down) (ms)	72.00	16.27
21.	Propulsion phase (ms)	80.00	14.86

(Source: Primary data collected by the author)

Table 2 shows the value of coefficient correlation of various independent variables with maximum locomotion velocity (dependent variable).

It is seen from the table that weight, height, leg length, stride length, stride frequency had higher positive correlation with maximum locomotion velocity. Similar result was found through a study conducted by Sodhi & Sidhu (1984). The study conducted by Kunz & Kaufmann (1981) indicated that American world class sprinters differed from Swiss decathletes in running the 100 m dash by having an optimal combination of a large stride length and higher stride frequency. It is also seen that contact phase, flight phase, braking phase and propulsion phase had higher negative correlation with maximum velocity. The result was identical with the study conducted by Plamondon and Roy (1984). They concluded that the two factors like braking phase (touch down) and contact phase were accounted for 80% of the variance in running velocity and sprint acceleration was mostly sensitive to the relative duration of the contact phase.

Table 2: Correlation of various independent variables with maximum locomotion velocity

Sl. No.	Name of the variable	r
1.	Weight (kg)	0.38*
2.	Height (m)	0.54*
3.	Leg length (m)	0.47*
4.	Leg power (m)	-0.07
5.	St. length (m)	0.69*
6.	St. frequency (st/sec)	0.45*
7.	Body inclination (deg)	0.11
8.	Angle of leg placement in braking phase (touch down) (deg)	0.52*
9.	Push-off angle (deg)	0.01
10.	Horizontal projection of CG in braking phase (touch down) (m)	-0.33
11.	Horizontal projection of CG in propulsion phase (m)	0.29
12.	Horizontal velocity of CG in braking phase (touch down) (m/s)	0.12
13.	Horizontal velocity of CG in propulsion phase (m/s)	0.34
14.	Velocity of swinging leg in braking phase (touch down) (m/s)	0.46*
15.	Velocity of swinging leg in propulsion phase (m/s)	0.24
16.	Angular velocity of thigh in propulsion phase (deg/sec)	0.08
17.	Contact phase (ms)	-0.42*
18.	Flight phase (ms)	-0.01
19.	Braking phase (touch down) (ms)	-0.37*
20.	Propulsion phase (ms)	-0.14

(Source: Primary data collected by the author)

It is seen from the table values of coefficients of correlation that major positive influencing factors for running performance were weight, height, leg length, stride length, stride frequency and velocity of swinging leg in braking phase. On the other hand, duration of contact phase and braking phase had negative influence. The result was similar to the studies conducted by Komi (1986), Mero (1988), Mero, Komi et al (1992) and Mero & Komi (1994). Among the factors, the increased body weight helps to generate more reactive force from the ground. These induce more forward propulsive force in the direction of motion which ultimately facilitates the athlete to run faster. Stride frequency is directly responsible for locomotion speed. As a mechanical principle, running velocity is the multiplication of stride length and stride frequency. Therefore, enhancements in stride length as well as stride frequency improve the running performance automatically. But the contact phase and braking phase show higher negative correlation with maximum velocity. Actually, in these phases the moving body tends to break the momentum and after touching the ground, it again increases its momentum in the shortest possible time. Therefore, the contact phase and braking phase should be minimal so that the velocity of the athlete may not be dropped to a large extent. The study conducted by Ciacci et al (2010) reestablished the fact and considered that 40-60% relative proportion of braking phase (touch down) and propulsion phase was to be optimal for efficient sprinting. It is seen from the table that leg length had positive correlation coefficient with maximum locomotion velocity. Actually this is the phase of growth and development. Therefore, the increase in leg length was eventually induced to greater stride length.

With the knowledge of relationship with maximum locomotion speed, effort was made to develop a regression equation with locomotion speed as the dependent variable and the others as independent variables. The regression equation is maximum velocity (m/s) = -1.246-0.0012 weight(kg) + 0.0110 height(m) - 0.1276 leg length(m) + 0.0213 leg power(m) + 4.1591 stride length (m) + 1.0120 stride frequency (st/s) +0.0003 body inclination (deg)- 0.0111 angle of leg placement in braking phase + 0.0086 push-off angle (deg) - 0.4237 horizontal projection of CG in braking phase (touch down) - 0.6240 horizontal projection of CG in propulsion phase - 0.0123 horizontal velocity of CG in braking phase (touch down) + 0.0623 horizontal velocity of CG in propulsion phase + 0.0108 velocity of swinging leg in braking phase (touch down) + 0.0155 velocity of swinging leg in propulsion phase - 0.00002 angular velocity of thigh in propulsion phase - 0.0068 contact phase(ms) - 0.0135 flight phase (ms) -0.0059 braking phase (touch down)(ms).

There may be some multi co-linearity effects between dependent and independent variables because a good number of variables were considered for the study. To remove the problem, principal component analysis test was done. In this regard, eigen value was very important. The eigen analysis of correlation matrix is given here.

Table 3: Eigen analysis of correlation matrix

Eigen value	5.0860	4.2043	3.0208	2.4414	1.7862	1.3830	0.9716
Proportion	0.242	0.200	0.144	0.116	0.085	0.066	0.046
Cumulative	0.242	0.442	0.586	0.702	0.788	0.853	0.900
Eigen value	0.8029	0.4001	0.2985	0.2179	0.1965	0.0996	0.0452
Proportion	0.038	0.019	0.014	0.010	0.009	0.005	0.002
Cumulative	0.938	0.957	0.971	0.982	0.991	0.996	0.998
Eigen value	0.0274	0.0078	0.0058	0.0029	0.0019	0.0002	-0.0000
Proportion	0.001	0.000	0.000	0.000	0.000	0.000	-0.000
Cumulative	0.999	0.999	1.000	1.000	0.000	0.000	-0.000

(Source: Primary data collected by the author)

It is clearly visible that six components had the eigen value greater than one (1). Therefore, in the principal component analysis test, the number of variables had been reduced to only six (6) components which covered approximately 85% of the result.

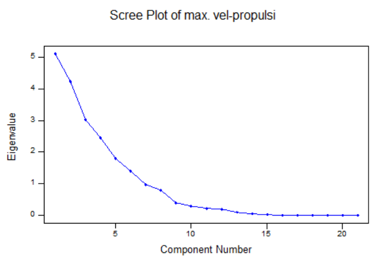

Fig 1: Scree plot of components for subjects

(Source: Primary data collected by the author)

The coefficients of various independent and dependent variables in the seven principal components are showed in the next table.

Table 4. Principal component analysis of various variables

Variable	PC1	PC2	PC3	PC4	PC5	PC6
Var. 1	-0.178	0.374	-0.079	-0.017	0.074	-0.133
Var. 2	-0.089	0.253	-0.171	-0.020	-0.345	0.200
Var. 3	-0.007	0.420	-0.042	-0.069	-0.235	0.042
Var. 4	0.036	0.379	-0.040	-0.135	-0.232	-0.139
Var. 5	0.044	0.030	0.349	-0.138	0.339	-0.000
Var. 6	-0.025	0.308	-0.021	-0.354	0.082	0.222
Var. 7	-0.211	0.105	-0.072	0.419	-0.013	-0.434
Var. 8	-0.031	0.136	0.074	-0.250	0.288	-0.007
Var. 9	-0.283	0.199	-0.084	0.300	0.114	0.312
Var. 10	-0.287	-0.113	0.162	-0.039	-0.441	0.145
Var. 11	0.279	-0.096	0.022	-0.354	-0.269	-0.267
Var. 12	0.259	0.264	-0.215	-0.019	0.326	-0.068
Var. 13	-0.183	-0.120	-0.199	-0.415	0.022	-0.373
Var. 14	0.151	0.306	0.278	0.085	0.248	-0.096
Var. 15	-0.371	0.045	-0.190	-0.174	0.100	-0.156
Var. 16	0.187	0.302	0.086	0.001	-0 .259	-0.086
Var. 17	-0.111	0.010	0.393	-0.036	- 0.088	-0.417
Var. 18	0.398	-0.059	-0.217	-0.016	-0.058	0.083
Var. 19	-0.207	-0.042	0.272	-0.375	0.045	0.349
Var. 20	0.392	0.028	0.213	0.096	-0.136	0.078
Var. 21	0.090	-0.107	-0.517	-0.125	0.073	0.023

(Source: Primary data collected by the author)

It is seen that the principal component 1 was more related with variables 18 and 20, that is, contact phase and braking phase. Principal component 2 was more related with variables 3, 4, 6, 14, 16, that is, height, leg length, stride length, horizontal velocity of CG in propulsion phase, and velocity of swinging leg in propulsion phase. Principal component 3 was more related with variables 5, 17, 21, that is, leg power, angular velocity of thigh in propulsion phase, and propulsion phase. Principal component 4 was more related with variables 6, 7, 9, 11, 13, 19, that is, stride length, stride frequency, angle of leg placement in braking phase, horizontal projection of CG in braking phase, horizontal velocity of CG in braking phase, and flight phase. Principal component 5 was more related with variables 2, 5, 12, that is, weight, leg power, and horizontal projection of CG in propulsion phase. Principal component 6 was more related with variables 7, 9, 13, 17, 19, that is, stride frequency, angle of leg placement in braking phase, horizontal velocity of CG in braking phase, angular velocity of thigh in propulsion phase, and flight phase.

Factor analysis was used to analyze inter relationship among the large number of variables and to explain these variables in term of their common underlying dimensions (factors).

Table 5: List of variables considered for factor analysis

Variable	Name
Var.1	Max. velocity(m/s)
Var. 2	Weight (kg)
Var. 3	Height(m)
Var. 4	Leg length(m)
Var. 5	Leg power(m)
Var. 6	Stride length(m)
Var. 7	Stride frequency(st/sec)

Var. 8	Body inclination(deg)
Var. 9	Angle of leg placement in braking phase(deg)
Var. 10	Push-off angle(deg)
Var. 11	Horizontal projection of CG in braking phase(m)
Var. 12	Horizontal projection of CG in propulsion phase(m)
Var. 13	Horizontal velocity of CG in braking phase(m/s)
Var. 14	Horizontal velocity of CG in propulsion phase(m/s)
Var. 15	Velocity of swinging leg in braking phase(m/s)
Var. 16	Velocity of swinging leg in propulsion phase(m/s)
Var. 17	Angular velocity of thigh in propulsion phase(deg/sec)
Var. 18	Contact phase(ms)
Var. 19	Flight phase(ms)

(Source: Primary data collected by the author)

Table 6: Rotated Factor Loadings

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7
Var.1	0.919	0.138	-0.067	0.032	0.016	-0.038	0.14
Var. 2	0.872	-0.076	-0.09	-0.055	-0.001	0.095	0.315
Var. 3	0.704	-0.23	-0.188	0.315	-0.174	0.069	-0.052
Var. 4	0.689	0.212	0.154	-0.034	0.235	-0.113	-0.283
Var. 5	0.584	0.494	-0.263	-0.432	-0.204	-0.035	-0.122
Var. 6	0.109	-0.973	-0.062	-0.052	-0.015	-0.064	-0.039
Var. 7	0.187	0.956	0.094	0.006	0.132	0.02	-0.007
Var. 8	-0.015	-0.597	-0.497	0.386	0.44	0.011	-0.139
Var. 9	0.283	-0.06	-0.936	0.064	0.088	-0.038	0.052
Var. 10	0.065	0.137	0.93	-0.133	0	-0.062	-0.085
Var. 11	-0.11	-0.26	0.125	-0.926	0.058	-0.052	0.075
Var. 12	0.057	0.428	0.209	-0.823	0.051	-0.023	0.102
Var. 13	0.052	-0.092	0.345	-0.098	-0.85	0.143	-0.071
Var. 14	-0.17	-0.018	-0.147	0.163	-0.698	-0.381	0.142
Var. 15	0.321	0.11	-0.496	0.344	-0.567	-0.035	0.201
Var. 16	0.108	0.536	0.037	-0.208	-0.164	0.77	-0.124
Var. 17	-0.074	0.103	0.483	-0.19	-0.263	-0.75	0.205
Var. 18	0.529	0.102	-0.293	-0.285	-0.089	-0.672	-0.053
Var. 19	0.127	0.043	-0.092	-0.118	-0.069	-0.148	0.923
% Var	**0.185**	**0.168**	**0.153**	**0.122**	**0.105**	**0.097**	**0.065**

(Source: Primary data collected by the author)

It is seen that factor 1 was greatly influenced by weight, height, leg length, stride length, leg power and, maximum velocity. So, this factor was related with anthropometrical dimensions and a few mechanical parameters. This factor controlled nearly 19% of the result. Thereby, anthropometrical parameters had a crucial role in running performance. Factor 2 was mainly influenced by leg power, stride length and stride frequency and it predicted approximately 17% of the result. Factor 3 was greatly influenced by angle of leg placement in braking phase and push off angle and it impacted approximately 15% of the result. Factor 4 was greatly influenced by horizontal projection of CG in braking and propulsion phases and it effected approximately 12% of the result. Factor 5 was greatly influenced by horizontal velocity of CG in braking and propulsion phases and it controlled approximately 11% of the result. Factor 6 was greatly influenced by velocity of swinging leg in various phases, angular velocity of thigh in propulsion phase and contact phase and it controlled approximately 10% of the result. Factor 7 was greatly influenced by flight phase and it predicted approximately 7% of the result.

4.0 CONCLUSION:

Within the limitation of the present study, following conclusions were drawn on the basis of the results obtained by statistical analysis of the data.

i) The maximum locomotion velocity of 17-19 year old boys is mostly determined by six groups of variables.

ii) Anthropometric variables particularly weight, height, and leg length play important role for maximum locomotion velocity at this stage.

iii) Stride length and stride frequency, angle of leg placement in braking phase, horizontal velocity of CG in propulsion phase, velocity of swinging leg in braking phase (touch down) influence the maximum locomotion velocity very positively at this stage.

iv) Contact phase and braking phase influence the maximum locomotion velocity very negatively at this stage.

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