The impact of hill training on middle and long distance athletes: with specific reference to oromia water works athletics club, Ethiopia

Nigatu worku and Dr. Aschenaki Taddese

* Nigatu worku, Addis Ababa University, Ethiopia
** Dr. Aschenaki Taddese, Addis Ababa University, Ethiopia

Abstract- The purpose of this study was to investigate the effect of 12 weeks hill training on the performance of middle and long distance athletes. The study used a longitudinal and controlled quasi experimental design. To test the hypotheses pre and post filed tests were conducted on VO_2 max, Resting heart rate, SE, race performance improvement, consistency of the improved performance and status of injury. Thirty two athletes divided randomly in to control and experimental group (n=32;18.8 ±3 years, 51.3 ± 5.2 kg, 1.68 ± 0.05 m) and passed through 12 week of intervention with two session of 40' - 60' hill workout a week to the commutative of 16 - 24 hours. During week 0, 6, 12 each subject complete three assessment testes, two records and additional three tests for experimental group at week 16, to assess the consistency of performance. Although the subjects were similar in all aspects prior to the pre-test was performed;12 minute cooper test (VO_2 max), resting heart rate (mean of three 15 sec. Rhr. count x 4), speed endurance (300 m anaerobic threshold test), race time records (from 4th to 16th weeks) and injury report records (from 2nd to 12th week) were administrated. The intervention group show significant improvement in VO_2 max, resting heart rate, speed endurance at week 6 ($p=0.00$, $\alpha=0.05$) and 12 ($p=0.00$, $\alpha=0.05$) and race time but the developed performance at week 16 have showed insignificant change. The control group showed insignificant change at either time points. There were no significant change in injury records between and within groups ($p=0.381$, $\alpha=0.05$). The study demonstrated that 12 week of hill training can significantly improve VO_2 max, Rhr., speed endurance and race performance in club level middle and long distance athletes and the developed performance is consistent over four week period and hill training by itself was not cause of athletic injury.

Index Terms- hill training, Vo2 max, Resting heart rate and speed endurance

I. Research design and method

Quasi experimental design was used to investigate the effects of 12 week hill training intervention on endurance, speed endurance, VO_2 max and resting heart rate was applied in club level middle and distance runner (800m – 10, 000m). A two group repeated measures (pre - during - and post-test) design was used. After eight weeks of off-season, subjects were randomly divided in to two groups. The two group consists of intervention group (endurance and hill training group n= 16; 18.8 ± 3 years, 51.3 ± 5.2kg, 1.68 ± 0.05m) and control group (only endurance training n = 16; 19 years, 52± 1.3kg, 1.69.0.03m). Prior to the start of the research all athletes and coaches were instructed not to deviate from their normal (800m - 10000m) endurance training. It is known that the control group did not employ any strength training as a part of their normal training program. The endurance training volume and intensity was controlled.

In addition to the endurance training, hill training was given twice per week thought out the study period (week 1 - 12). All the hill training sessions were provided by experienced coaches of the club.

II. Sample and Sampling Technique

Thirty six competitive club level distance athletes (800m - 10,000m) participated in this study. However, due to the selection for national and international cross country competition, thirty two subjects (n = 16; 16; 18.8 ± 3 years, 51.3 ± 5.2 kg, 1.68 ± 0.05m as experimental) and (n = 16; 19 years, 52± 1.3kg, 1.69 ± 0.03m as a control group) completed the study. The preliminary information assures that the subject didn't have any strength training with in the past five month (July – November 2016). All subject were taken from Oromia water works sport club.

III. Data Collection Instruments

During week (0, 6, 12) each subject completed two assessment days. VO_2 max, speed, and endurance. Resting heart rate taken at one of the days early in the morning while all subjects were on their bed. All VO_2 max, speed endurance and resting heart rate were under taken at the same time and date to avoid diurnal variation on the performance. There were 48 hours between each testing days.

To control the effects of diet and physical readiness, each subject was asked to consume habitual diets and avoid vigorous exercise 24 hours prior to assessments. For resting heart rate assessment subjects were oriented to stay on their bed until their heart rate count was conducted.

Table 1. Dependent Variables and their Respective Tests

No	Criterion Variables	Test Item	Unit of Measurement
1.	Cardio-respiratory Endurance (VO_2 max)	Cooper's 12 minutes Run	Meters /12min
2.	Resting Heart rate	Heart beat per minute	Beat/minute
3.	Speed endurance	300m anaerobic threshold	Second
4.	Race performance	Race performance records	Meter/second
5.	Acquired performance consistency	Tests comparison	-
6.	Status of athletic injury	Injury report records	Numbers

IV. Data Analysis

The collected data in this study was analyzed depending on the type of data collected. First, data from pre, during and post- test results of the experimental group was analyzed to see whether the athletes attended in planed and implemented hill training program improved their performance or not. Second, data from the Control group test was analyzed to compare and verify the validity of hill training method, if it brought significant impact on the improvement and consistency of the long distance athletes' performance. The study was also measured whether hill training helped athletes to maintain their performance for longer duration or not. Finally, data recorded for injury report was analyzed to check if hill training minimized the risks of athletics injuries. Independent variables were defined in terms of the different interventions (experimental vs. control) and the three measurement points (pre - test vs. mid-test vs. post-test). All data set were presented as mean ± standard deviation or percentage change. Descriptive (percentage, average, mean and median) and inferential statistics (graph, histogram and bar charts) was used to analyze the club's variation and performance change within and between athletes. To test for differences between groups at week zero, an independent t-test was used. For each group, measurement values are recorded at before, during and after. Experimental training method and difference between groups compared using a one-way repeated measure ANOVA was used. The level of significance was set at $P \leq 0.05$. IBM SPSS Statistics version 20 software was used for all statistical analysis.

The importance of hill training methods on improvement of athletes VO2 Max level.

The mean weight value of subjects of normal training method (control) of this study was 51ml/kg/m and the mean distance was 3573m before test was conducted. Similar pre measurement was found for treatment group with hill training, which was almost equivalent figure, was recorded.

Although the subjects were similar in all aspects prior to the test was performed, significant difference in VO_2 max was resulted after hill training was systematically applied. Hill training was measured after it was implemented in three methodological periods and the initial value of athletes were different ($p=0.00$, $\alpha=0.05$).

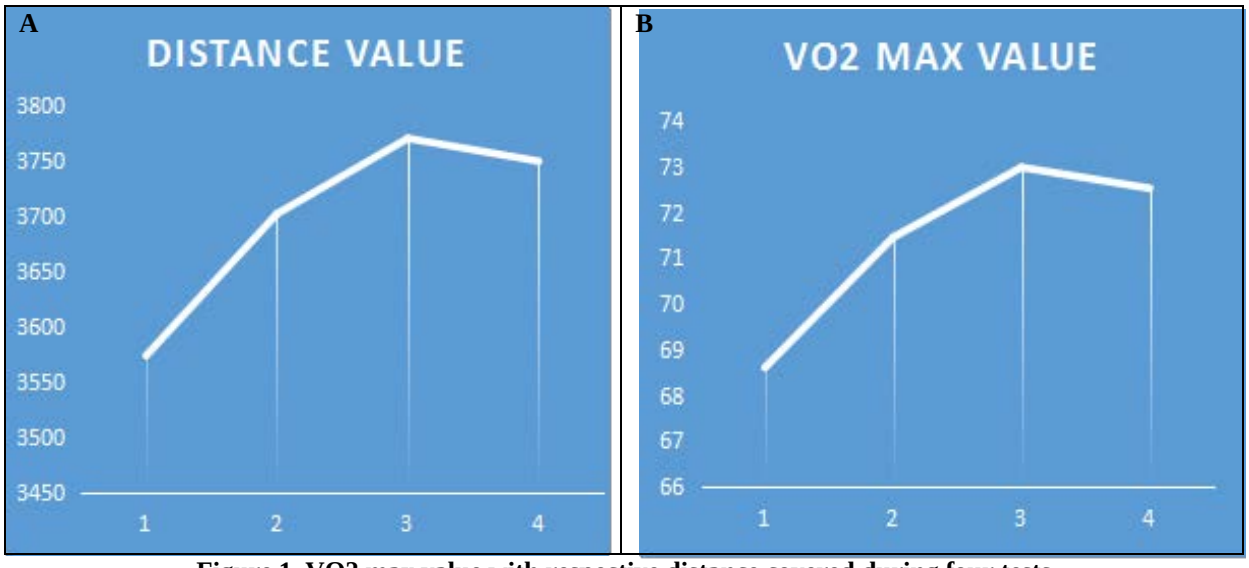
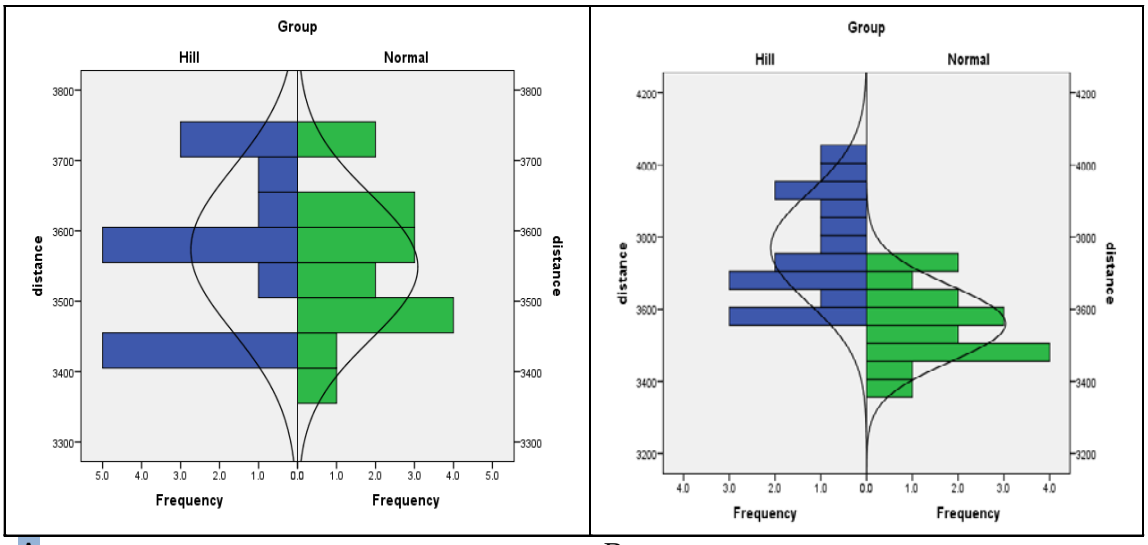


Figure 1. VO2 max value with respective distance covered during four tests

Vo2 max show progressive increment during the intervention and slight decrease four week after intervention.

A. Distance value for all tests; B. VO_2 max value of all tests of the hill training groups.



A B

Figure 2: the pre-test value of distance covered for vo2 max test and vo2 max value

The hill training group showed significant improvement and the control group has showed insignificant change which indicates that hill training has positive effect on the improvement of vo2 max value

Table : T - test for testing the difference in VO2 max among groups

		Sum of Squares	df	Mean Square	F	Sig.
VO_2 pre test	Between Groups	4.500	1	4.50	.67	.41
	Within Groups	199.37	30	6.64		
	Total	203.87	31			
VO_2 test2	Between Groups	180.50	1	180.50	20.48	.00
	Within Groups	264.37	30	8.813		
	Total	444.87	31			

Analysis of paired t test shows that there was significant progress ($p=0.00$, $\alpha=0.05$) in the attainment of VO_2 max in hill training from than normal method.

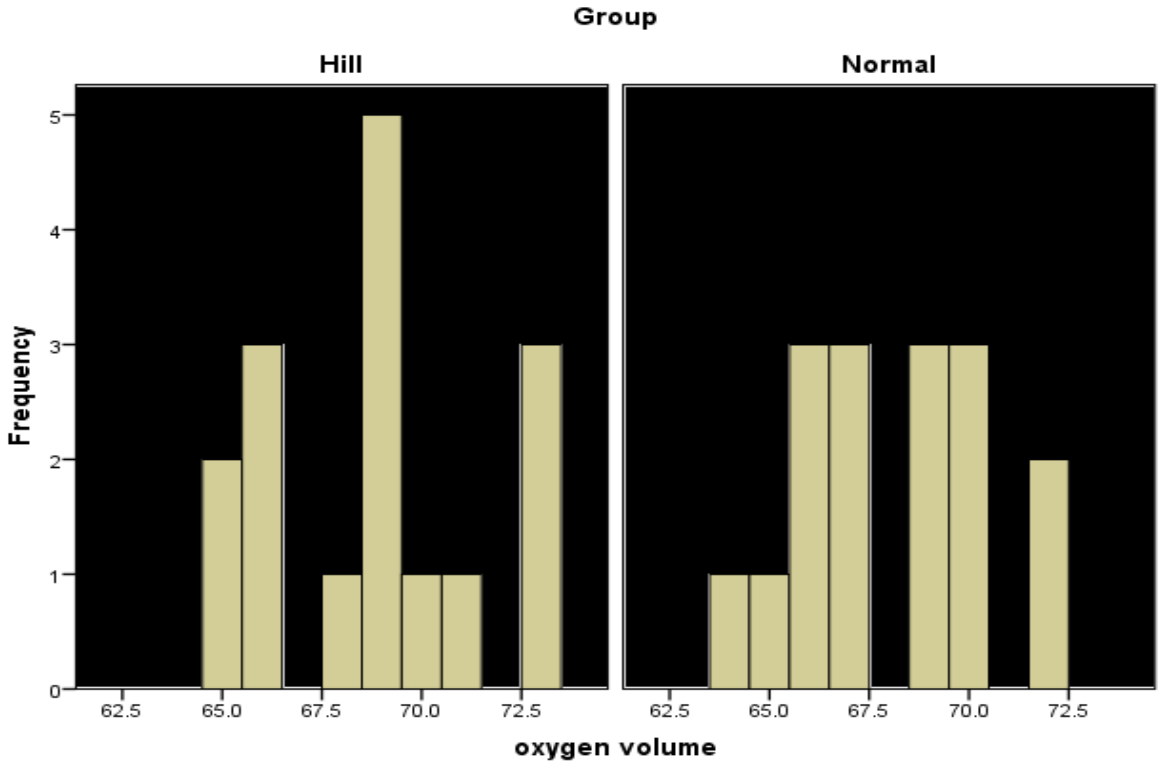


Figure 3: post vo_2 max value of experimental and control group

All of the subjects in treatment group were seen showing change in first post test and middle stage test. The test for attainment of the improved VO_2 max shows there is consistency of VO_2 max value. The VO_2 max value of the control group show similar result .

Table 3: Paired Samples Test to analysis the progressive improvement of VO2 max in the treatment group

Paired Differences									
Pared testes		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
Pair 1	vo_2 pre test - vo_2 test1	2.750	1.342	.335	-3.465	-2.035	8.199	15	.000
Pair 2	vo_2 test2 - vo_2 test3	.625	.500	.125	.359	.891	5.000	15	.000
Pair 3	vo_2 test1 - vo_2 test2	1.500	1.211	.303	-2.145	-.855	4.954	15	.000

The impact of hill training on the resting heart rate of the athletes

Similar to VO_2 max The magnitude of resting heart rate was similar in all athletes of the study. Although after hill training was implemented and tested there was a significant change for experimental subjects ($p=0.00$, $\alpha=0.05$) while no change was recorded when measurement of the heart rate checked for normal groups without the hill training implemented ($p=0.141$, $\alpha=0.05$).

Table 4: Independent Samples Test to analysis the change in resting heart rate

T - test for equality of mean								
		t	D	Sig.	Mean	Std.error	95% confidence	
							Lower	Upper
Pre Rhr.	Equal	1.510	30	.141	1.381	.952	-506	3.381
Post 2 Rhr.	Equal variance assumed	9.222	30	0.00	-9.938	.969	-10.917	-6.958

The hill training method improves the resting heart rate even after a few training sessions and the progress is evident from the table bellow, which depicts complete transformation of the athletes physiological stability and better condition through every stage of the test conducted.

Table 5: Paired Samples Test of step wise tests for checking impact of hill training method on resting heart rate of athletes of different event

		Paired Differences					t	df	Sig. (2tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Diff				
					Lower	Upper			
Pair 1	pre RHR - Post 2 RHR	8.813	5.767	1.019	6.733	10.892	8.645	31	.000
Pair 2	Post 1 RHR - Post 3 RHR	8.688	3.459	.865	6.844	10.531	10.04	15	.000

Resting heart rate

Resting heart rate value have no difference before the intervention, but the hill training group result show 21% decreases in count values while the control group change only 6% which was very little. This result indicates that resting heart rate improved with hill training method

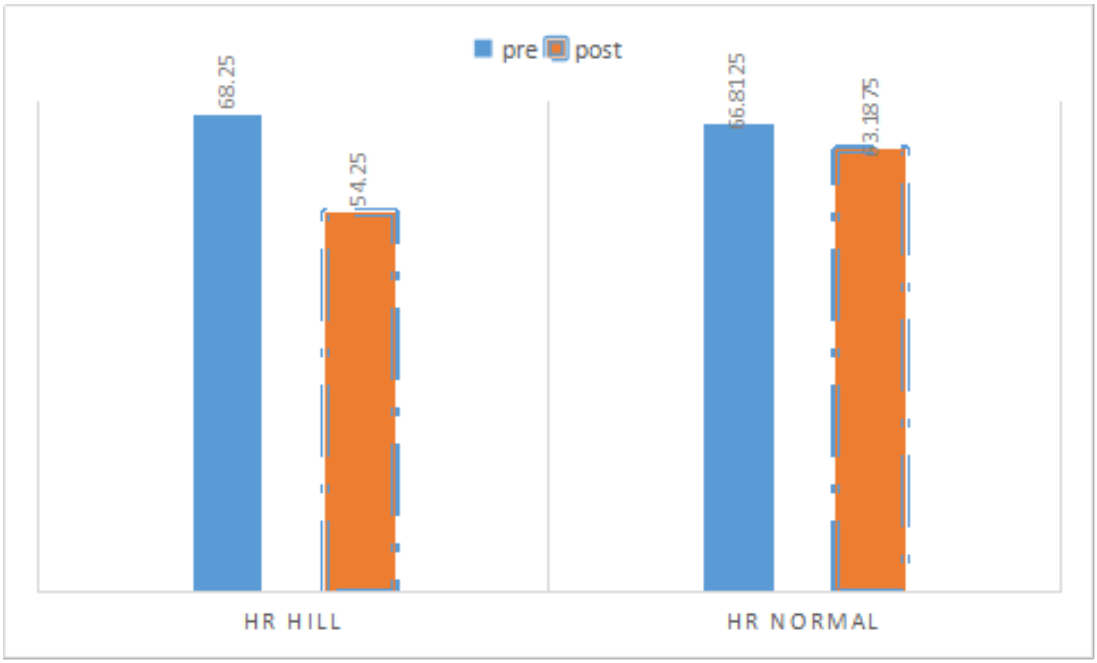


Figure 4: Resting heart rate across groups for pre and post tests

Significance of hill training on the improvement of speed endurance

The data from pre test shows that athletes were not different in their speed endurance. This pattern was completely inverted when the groups were treated in different training technique, the group with hill training workout showed significant upgrade in the speed endurance they scored before. But for the athletes in normal training techniques were show no difference that means they only attain their pre tested speed.

Table 6: Pre hill workout test showing the level of variation among groups of training experiment

		t-test for Equality of Means				
		t	Df	Sig. (2-tailed)	Mean Difference	Std.Error Difference
Pre. Speed End.	Equal variances assumed	.65	30	.52	.75	1.16

The value of speed endurance test show progressive decrease, in the same manner resting heart rate improved significantly during and after intervention. The resting heart rate and speed endurance show direct relation in this study.

Figure 5: The relationship between resting heart rate and speed endurance for hill training method using group

Table 7: Independent Samples Test to check the difference among groups of training methods

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Post 2 Speed End.	Equal variances assumed	-10.15	30	0.00	-7.500	.738	-9.008	-5.992

The tests among the experimental group to check if there is progressive improvement showed significant change in all test stages (table 12).

Table 8: Athletes test result and test difference for speed endurance by Paired Samples Test

Paired difference									
		Mean	Std. deviation	Std. error mean	95% confidence		t	d	Sig. (2tailed)
					Lower	Upper			
Paire1	Post 1 speed end Post 3 speed end	5.37	2.60	.65	3.98	6.76	8.25	15	0.00

The influence of hill training on the race performance of the athletes

Data was used to predict the persistence of the performance attainment after hill training was used as a new improved system of coaching. Performance prediction showed that the effectiveness of hill training in boosting physiology and race performance of an athlete. Although it is true for any method of training, hill training should be used systematically to keep up with the rate of change.

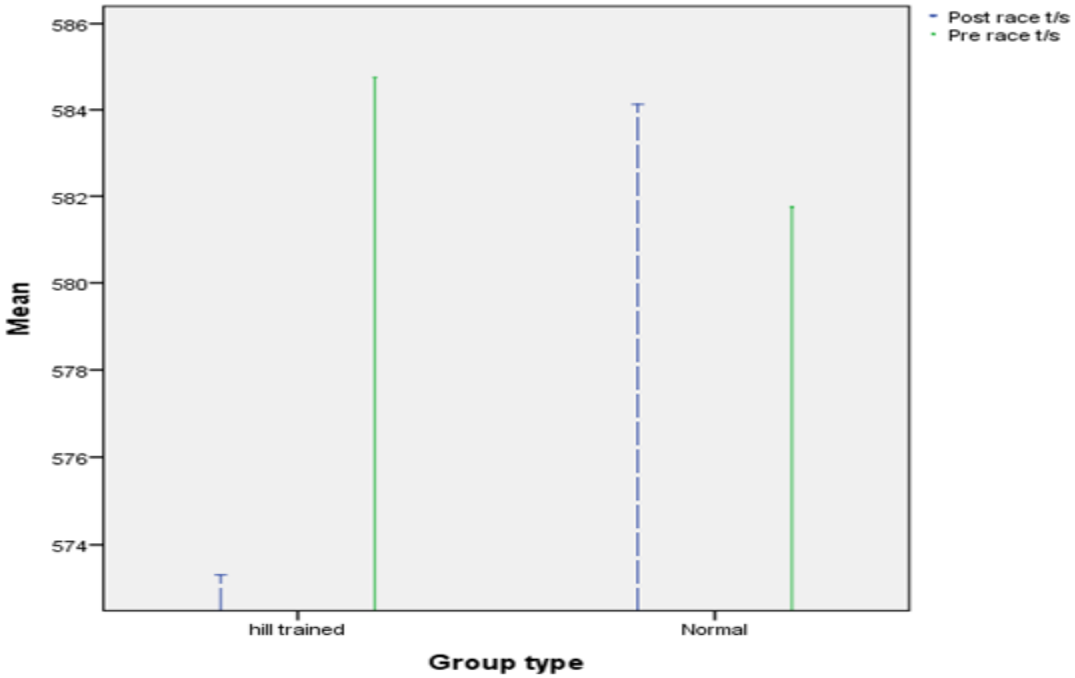


Figure 6. Race time comparison of experimental and control group

The hill training (experimental groups) have shown a significant decrease in their race time. The result indicate that all athletes improve their race time significantly after the intervention. As seen on (figure 6) the post result of experimental group indicate dramatic change in race performance while the control group show little change in race performance.

Consistency of acquired performance

The result indicates that physiological and physical quality of the athletes have improved by hill training program given in 12 weeks of intervention and additional test was conducted to see the consistency of the developed performance. This was evident from the result in increased mean frequency value, where the distribution of test measurements for different parameters are indicated high for all subjects and test conducted (Figure 7 A, B. speed endurance value during intervention show 41.5± 2 and after four week 42.4± 1.9 which show the values were found similar four week after hill method. This change in performance were found consistent . In the same manner the vo2 max level of the testes during the intervention and four week after the intervention have been compared and show insignificant change(figure 7 C, D the VO_2 max value during intervention shows the mean value 73 ± 3.4 and the test result after four week also show similar mean value 72.4 ±3.3). this result show the consistency in vo2 max level. In addition the heart rate value was computed by its during and after four week test value which similarly show insignificant difference (Figure 7, E,F General the result of all the three performance indicative variables have shown similarly insignificant change value which lead us to conclude that the performance of the athletes showed consistency.

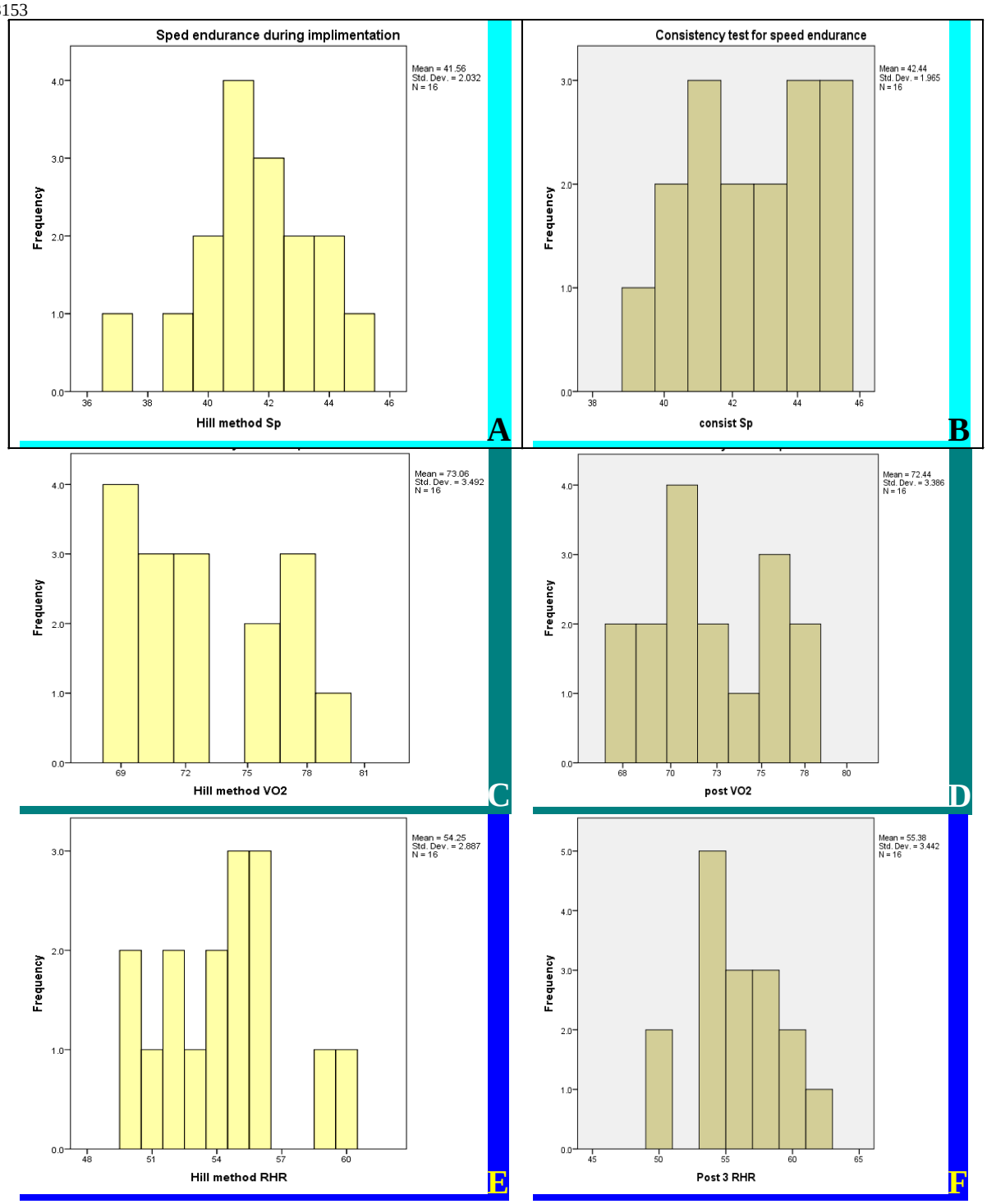


Figure 7: The impact of hill training on performance consistency

Implication of hill training on the risks of athletic injuries

Table 9: Athletes injury report result

		No of athletes	Injury re	difference	%
INJURY REPORT	Experimental	16	2	14	12.5%
	Control	16	4	12	25%
	Total	32	6	26	37%

This research found that the presence of hill training is not a cause of athlete injury, Analysis of variance for injury resulted insignificant deference (12.5% and 25%) among treatment and control subjects respectively.

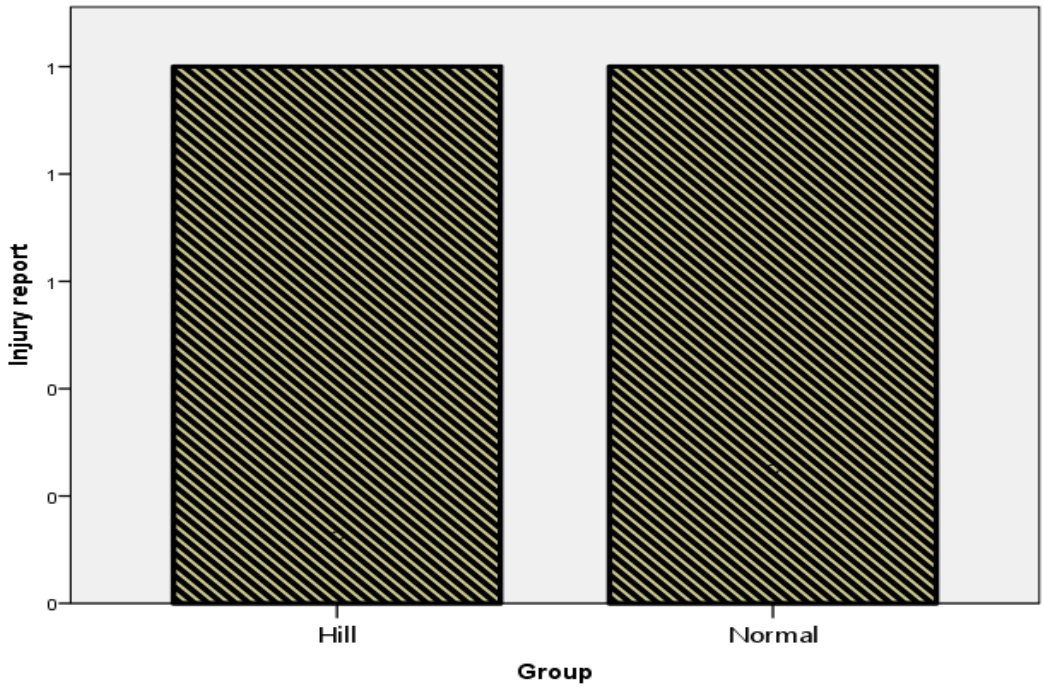


Figure 8: Comparison of injury report of the groups

The study shows that hill training has no significant effect on the athletic risks of injury. There is no change is observed on experimental group that indicate carefully planed and implemented hill training could not be the cause of athletic injury.

V. Discussion

The aim of this study was to investigate the effect of a twelve week hill training intervention on key physiological and physical performance indicators, vo2 max, resting heart rate, speed endurance, race performance, the consistency of the developed performance and status of athletic injury in competitive club level middle and long distance runners. The main finding of this study was that hill training can significantly improve vo2 max, Rhr, speed endurance, race performance and the finding also show that the is the consistency of developed performance over 4 week period in competitive distance runners. Interestingly, the improvements in VO_2 max, speed endurance and race performance were attained without significant changes in risks of athletic injury status. These results strongly support the application of hill training on the distance running athletes; demonstrating that to optimize endurance performance, strength training should be a vital component in the physical preparation of distance runners.

Vo_2 max: - The maximal oxygen uptake (VO_2max) has been suggested to be the single most important physiological capacity in determining endurance running performance. Radovanovic (2009) define Vo_2 max as one of the most objective measures that can be used to assess aerobic or cardio-respiratory endurance is maximum oxygen consumption. The VO_2max value is a direct indicator of the ability to supply the energy for muscle contractions during the process of anaerobic exercise.

Athletes can generally improve their absolute VO_2max values by 15 to 20% and their relative values by 20 to 40% (Maglischo, 2003). A high VO_2 max is indicative of an enhanced ability of the aerobic systems to provide energy to the working muscle.

As explained by Beattie (2014), VO_2max and resting heart rate are accepted as the two most important performance indicators for distance running. The enhancement in VO_2max may therefore have been related to an increased training intensity rather than an increase in training volume (Midgley et al., 2007) and Shaw (2014) showed that VO_2 max represents the ability of a runner to translate energy production at a cellular level into running locomotion. An economical runner will use less energy for a given workload and spare vital reserves for maximal and supra-maximal stages of competition (i.e. a sprint finish).In this study, the hill training group displayed a significant ($p=0.000$, $\alpha=0.05$) improvement in VO_2 max from week 0 to week 12. These improvements in VO_2 max occurred with additional significant improvements on resting heart rate. The control group showed no significant ($p= 0.41$, $\alpha=0.05$) change in VO_2 max throughout the 12 weeks.

Resting heart rate: - RHR is dictated by a complexity of factors such as volume and intensity of endurance training, nutrition and environment (Barnes, 2015). These results are evidence for effect of the application of hill training on the distance running athlete of various events; explains that to optimism race performance, hill training could be an optional method in the physical preparation of athletes for competition**.**

RHR represents the ability of a runner to translate energy production at a cellular level into running locomotion. It is better achieved by a systematic use of training methods such as hill workouts. This effect of hill training method can be maximized through management of intensity of endurance training. In this study, the effect of hill training in all event and in all test scenario of test group displayed a significant change for experimental subjects ($p=0.00$, $\alpha=0.05$) improvement and showed considerable consistency while insignificant change($p=0.141$,$\alpha=0.05$) was recorded when measurement of the heart rate checked for normal groups without the hill training.

Speed endurance: - Hill running is 'speed work in disguise'. It can be used in place of grueling track workouts to improve your anaerobic efficiency (Jack Daniels,1998, pg. 179), it is almost as effective in building aerobic power as track interval training and by improving VO_2 max, boost running economy and buffer anaerobic (Lactate) threshold significantly improve speed endurance. Many scientific studies indicate that the lactate threshold (anaerobic threshold) is one of the best predictors of distance running performance. A faster threshold speed indicates that the athlete may perform at this speed for a fairly long period of time (possibly up to a marathon) without experiencing undue fatigue. It was found that when highly-trained distance runners added a weekly 20 min run at the lactate threshold the speed at which the threshold was reached increased after 14 weeks of such training (Sjodin et al.,1982).

Speed endurance and VO2max have strong associations with both middle- ($r = 0.71$) (Ingham, 2008) and long-distance ($r = 0.89 – 0.94$) (Noakes,1990) performance in elite running populations. These relationships are most likely due to vVO_2 max & speed endurance being a composite variable of both speed endurance and maximal oxygen consumption. Interestingly, the anaerobic threshold test (300m anaerobic endurance test) was found to be strongly associated with VO_2max and resting heart rate($r = 0.85$) and maximal-velocity sprinting ($r = 0.96$) (Paavolainen, 2000); emphasizing the anaerobic system's contribution in providing energy production for race velocities at and above VO_2max (Nummela, 2006). In this study, the hill training group showed a significant improvement in speed endurance ($p=0.00$, $\alpha=0.05$) during the first six weeks of hill training (week 0→6), and a significant ($p=0.00$, $\alpha=0.05$) improvement throughout the 12 weeks. The control group however showed no significant changes in speed endurance throughout the 12 weeks.

Reduction of risk of injury: The improvement of VO_2 max, strength, speed endurance, vVO_2 max and running economy results on significant improvement on race performance and it was consistent with proper training and follow up method. This study showed that hill training have insignificant effects on the risks of athletics injury which is 12.5% or 2 athletes out of 16 for the experimental group while 25% or 4 athletes out of 16 report injury. From this result it is possible to conclude that hill training was not the cause for athletic injury specially achilis tendon , heel knee and hamstring so it could not be the fear for coaches to include hill training in their training plan and provide for their athletes.

VI. Summary

The main finding of this study demonstrated that 12 weeks of hill training can significantly improve speed endurance qualities, as well as physiological markers of resting heart rate and VO_2max ability of club level distance runners. Therefore, the research hypotheses significant changes in VO_2 max, resting heart rate, speed endurance, race performance and consistency of performance is accepted; the research hypothesis for a reduction of athletic injury status is rejected. Interestingly, the improvements in speed endurance were attained without significant changes in risks of injury. A significant improvement was gained through the 12 week period, and it maintained over four week period as programming shifted towards hill free training. However, within the control group, physiological, physical and important strength quality of running remain unchanged throughout the study period. Upon consideration of the limitations of current research, I believe that if more quantitative scientific research proved the effectiveness of the current training methods, it could be used for the country level. This study showed that in distance runners those who do not perform strength training, hill training can be considered as solution, especially club level coaches should consider including hill workouts in their training method. More over for distance runners who are already on pick may need to place a greater emphasis on keeping the performance consistence. A general strength orientated hill training program is an appropriate and efficient method for improving both strength and speed endurance ability in distance runners. Well planed hill training program can significantly improve VO_2 max, resting heart rate, speed endurance and race performance of middle and long distance athletes. Hill training has no negative effect on the risks of athletic injury. To enhance the performance of middle and long distance events athletes, the coaches have to include hill training workouts in their training plan. Hill is not the cause of athletic injury.

REFERENCES

[1] Barnes KR, Kilding AE. Strategies to improve running economy. *Sports Med 507* **45**(1):37-56, 2015.

[2] Nummela A, Keranen T, Mikkelsson LO. Factors related to top running speed and economy. *Int J Sports Med* **28**(8): 655-61, 2006.

[3] Foster, C., Hector, L. L., Welsh, R., Schrager, M., Green, M. A., and Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. *European Journal of Applied Physiology*, **70**, 367-372.

[4] Beattie K, Kenny IC, Lyons M, Carson BP. The effect of strength training on performance in endurance athletes. *Sports Med* **44**(6): 845-865, 2014.

[5] Berryman N, Maurel D, Bosquet L. Effect of plyometric vs. dynamic weight training on the energy cost of running. *J Strength Cond Res* **24**(7): 1818-1825, 2010.

AUTHORS

First Author – Nigatu worku, Addis Ababa University, Ethiopia
Second Author – Dr. Aschenaki Taddese, Addis Ababa University, Ethiopia