Empirical Effect of Moderate Altitude Exercises on Athlete and Non-Athlete: A Systematic Literature Review

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ABSTRACT

Moderate Altitude training is commonly categorized as 2000M to 3000M near sea level. There was still a lack of studies about the low to moderate altitude training effect compared to high altitude (3000M to 5000M) training, especially for sedentary people. The research question was to identify the physiological effects of exercise at moderate altitude among athletes and non-athlete. Thus, the objective of this paper was to systematically review the literature on the empirical effects of moderate altitude exercise on athletes and non-athlete. ROSES review Protocols were employed prompting researchers to ensure they offer the right information with the correct level of details. The keyword of moderate altitude training, athlete, and sedentary were used and expanded using search string, thesaurus, and expert opinion. Handpicking and technique were used on two Databases Scopus (326) and Science Direct (2628). The article was then screened with inclusion criteria were 1) 5 years of studies, 2) journal article, 3) languages, 4) measurement tools used, and 5) availability of journal. Appraise the quality of the article done by 3 persons, consisting of the author and co-authors to subjectively filter based on a perception of the article. Only high and moderate levels in terms of 1) statistical analysis, 2) measurement scale, 3) tools will be reviewed. High and moderate quality should determine by reading and referring to assessment tools, scale, and checklist using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Finally, only n=25 articles were reviewed, and data were extracted using the inductive thematic analysis technique. The general finding is moderate altitude training can increase physical performance and the level of physical fitness of athletes. There was still a lack of study on the effect among non-athletes. Thus, future studies need to investigate the effect of exercise at moderate altitude among non-athlete or sedentary people.

Keywords: Moderate Altitude Training, Athlete, Sedentary.

INTRODUCTION

Moderate Altitude Exercise

Professional athletes have been practicing altitude training worldwide, especially for high altitude training, which significantly affects athlete performance [23]. Altitude training was acknowledged with many modalities such as “live high, train low’ [22]. Previous studies show that high altitude training may affect the endocrine systems, energy intake, resting metabolic rate, and body mass. Besides, the resting metabolic rate is also increased [29]. Nowadays, current research is more focused on moderate altitude since it may benefit athletes and sedentary people without adversely affecting their health [16]. Low to moderate altitudes and targeting adequate energy intake is essential for optimizing health and appear to be emerging factor associated with optimizing altitude adaptations [10].

There are also many studies done using lab equipment that can mimic hypoxic conditions in moderate and high altitudes for both athletes and non-athlete [19]. Previous studies also found that the hypoxia-induced adaptive effect in the human organism is similar to those resulting from sea-level athletic training [23]. Hypoxia is defined as a reduced (or insufficient) O2 supply to tissues caused by decreases in O2 saturation of arterial blood [11]. Hypoxic conditioning (HC) relates to passive (i.e., during rest) or active (i.e., during exercise) exposure to systemic (whole-body) and local (tissue) hypoxia, resulting in a decrease in arterial O2 availability [13].

Moderate altitude commonly is categorized between 2000–3000 meters near sea level while high altitude is 3000 – 5000 meters, low altitude as 500 – 2000 meters, 500 meters, and below categorized as near sea level [29]. It is known that resting arterial oxygen saturation (SaO2) is well maintained at low altitudes between sea level and 1500m [14]. The SaO2 starts to progressively decline at higher altitudes as a result of a partial oxygen pressure drop. Although SaO2 can reach lower than 80% depending on altitude level, the fractional concentration of oxygen remains the same. Therefore, inspired oxygen pressure decreases, which results in hypoxia that disturbs the balance of homeostasis. Several physiological and metabolic regulations are adjusted to maintain tissue oxygenation in unstable homeostasis conditions. The regulations are generally attributed to hematological, cardiovascular, and ventilator mechanisms [15]. More significant acute hormonal and metabolic stress responses following resistance exercise under hypoxic conditions [22].

For non-athlete, most previous studies were done to combat obesity and metabolic syndrome [16] [30]. Several studies have reported weight loss, reduced blood pressure, and improved metabolic function after a 1- to 3-week residential stay (e.g., hotel and food provided, light entertainment activities throughout the day, no structured exercise program) at terrestrial altitude (1,500– 8,800 m). this training strategy has shown its beneficial effects on cardio-metabolic health and weight management in untrained individuals [19]

METHODOLOGY

The Protocol – ROSES

The present study was guided by ROSES review protocol. ROSES or RepOrting standards for Systematic Evidence Syntheses are explicitly designed for systematic review and maps for the environmental management field [32]. ROSES aims to prompt researchers to ensure they offer the right information with the correct level of detail. Based on this review protocol, the authors started its SLR by formulating appropriate research questions for the review. Then, the authors explain the systematic searching strategy, which consists of three main sub-processes: identification, screening (inclusion and exclusion criteria), and eligibility. Then, the authors proceed to the appraisal of the quality of selected articles, whereby the authors explain the strategy applied to ensure the quality of the articles to be reviewed. Lastly, the authors explain how the data were abstracted for the review and how the abstracted data were analyzed and validated [31].

Formulation of Research Questions

The formulation of the research question for this study was based on PICo. PICo is a tool that assists authors in developing a relevant research question for the review. PICo is based on three main concepts: Population or Problem, Interest, and Context. Based on these concepts, the authors have included three main aspects in the review, namely athlete and non-athletes or sedentary (Population), moderate altitude (Interest), and performance (context). Thus, it then guides the authors to formulate their central research question, what are the passive and active effects of exercising at moderate altitude among athletes and non-athletes?

Systematic Searching Strategies

There are three main processes in the systematic searching strategies: identification, screening, and eligibility.

Identification

Identification is a process of searching any synonym, related terms, and variation for the study's main keywords: climate change, adaptation ability, and indigenous people. It aims to provide more options for the selected database to search for more related articles for the review [31]. The keywords are developed based on the research question and the identification process relies on an online thesaurus, keywords used by past studies, keywords suggested by Scopus, and keywords suggested by experts. The authors managed to enrich the existing keywords and developed an entire search string (based on Boolean operator, phrase searching, truncation, wild card, and field code functions) on the two primary databases, namely Scopus and Science

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Direct. These two databases have the ability to be leading databases in a systematic literature review due to several advantages it possesses such as advanced searching functions, comprehensive (indexing more than 5000 publishers), control of the articles' quality, and multidisciplinary focus, including environment management related studies [31]. The search process in these two databases, namely Scopus and Science Direct, resulted in a total of 2990 articles.

Screening

This study screened all the 2990 selected articles by choosing the criteria for article selection which is done automatically based on the sorting function in the database. The selection inclusion criteria were 1) 5 years of studies, 2) journal articles, 3) languages, 4) measurement tools used, and 5) availability of journal, the research question, and range of period that they were able to review. This process excluded 2371articles as they did not fit the inclusion criteria and removed 401 duplicated articles. The remaining 218 articles were used for the third process eligibility.

Eligibility

Eligibility is the third process where the authors manually monitor the retrieved articles to ensure all the remaining articles (after the screening process) are in line with the criteria. This process was done by reading the title and abstract of the articles [31]. This process excluded 173 articles due to its focus on high altitude rather than moderate altitude and enjoyment and psychological aspect rather than adaptation to altitude change. Some other articles focused on the acute effect of passive acclimatization and focused on review, not empirical data. The methodology section is not clearly defined and published in the form of a chapter in a book. Overall, there were only 45 selected articles.

Quality Appraisal

To ensure the quality of the articles' content, the remaining articles were presented to two experts for quality assessment. Experts should rank them into three quality categories: high, moderate, and low. Only articles categorized as high and moderate should be reviewed. The experts focused on the articles' methodology to determine the quality's rank. For the article to be included in the review, both authors must mutually agree that the quality must be at least at a moderate level. They discussed disagreements before deciding on the inclusion or exclusion of the articles for the review. This process ranked 18 articles as high and seven articles as moderate. Thus, all the remaining articles were eligible for review.

Data Abstraction and Analysis.

This study relied on an integrative review. This technique allowed diverse research designs (quantitative, qualitative, mixed-method) to be included in the review. Synthesizing or analyzing integrative data using qualitative or mixed-method methods enables the researcher to conduct iterative comparisons across the primary data sources [31]. The 25 articles were read thoroughly in the abstract, results, and discussions sections.

Data abstraction was conducted according to the research questions. It indicates that any data from the reviewed studies that can answer the research questions were abstracted. Subsequently, the researcher performed a thematic analysis by noting patterns and themes, clustering, counting, and noting similarities and relationships within the abstracted data [31].

Thematic analysis is considered the most suitable for synthesizing a mixed research design (integrative). It is explained as a descriptive method that reduces the data in a flexible model that merges with other data analysis techniques. The initial step of thematic analysis is to generate themes [31]. The authors tried to identify patterns that emerged among the abstracted data of all reviewed articles. Any similar or related abstracted data were pooled in a group, and eventually, six main groups were created.

The following process involved reviewing the accuracy of these themes. In this process, the authors re-examined all the themes generated to ensure their usefulness and accurate data representations. Within this process, two themes were excluded, one theme being related to immune systems and another under the theme of psychology and tourism.

Once the process is completed, the finalized patterns are four main themes. Afterward, the authors proceeded to the next stage by naming the themes for each group. The development of themes was done using this technique in a group consisting of corresponding authors and co-authors with the theme of the findings. During the development of the themes, the researcher discussed any inconsistencies, thoughts, puzzles, or ideas that could be associated with the interpretation of the data until the point of agreement on the adjustment of the developed themes and sub-themes. The developed themes and subthemes were presented to two-panel experts. The experts were asked to evaluate the six themes subjectively. Both agreed that the themes were appropriate and relevant to the results of the review.

RESULTS

Background of Selected Articles

The review managed to obtain 25 selected articles. Based on the thematic analysis, four themes were developed, namely aerobic and anaerobic capacity, types of training, physiological changes, and lastly, hypoxia or Altitude Training. All 25 articles have complied with inclusion criteria 1) 5 years of studies, 2) journal articles, 3) languages, 4) measurement tools used, and 5) availability of journal, the research question, and range of period that they were able to review.

Themes and Sub-Themes

Aerobic and Anaerobic Capacity

Previous studies on non-athlete overweight males, for instance, passive acute mild altitude increased energy expenditure and altered fuel utilization by reducing glucose and lipid oxidation for the energy source [17]. Further passive moderate altitude magnified these metabolic adjustments from exposure of 7 days [16].

The effectiveness of mild altitude training as a means of improving the performance of athletes associated with increased endurance has been proved by many researchers, including athletes in sports that require power, speed-force combination, and complex coordination [18]. Moderate altitude training effectively improves the physical fitness and functional performance of athletes specializing in running medium distances [27].

A training camp at moderate altitude did not alter pulmonary di using capacity in elite swimmers [20]. Superior lung diffusion capacity has been reported in native highlanders [12]. They also have a lower percentage likelihood of becoming obese [16]. It could also be suggested that multiple combinations of exercise (cardiovascular and strength) carried out in hypoxic conditions are more beneficial than cardiovascular exercise alone to reduce blood pressure in obese populations [16].

There is increasing evidence that acute exposure to moderate altitude improves e plosive actions in basic strength exercises (bench-press, back squat, and squat jump exercises and in sports activities such as sprints, jumps, and throws. This improvement may be due to a proportionately reduced aerodynamic resistance to the square of the velocity when cycling, running, or throwing objects [1]. No meaningful changes in explosive strength performance were observed [22].

Types of Training

High-intensity interval training (HIIT), such as sprint interval training (SIT) with supramaximal intensity found to be a good combination with hypoxia to have significant performance improvements compared to low-intensity training [19]. Remote effect of strength training performed at the pre-altitude stage that sometimes exerted a potential effect on aerobic capacity and usually improved athletic performance [23]. However, Intermittent hypoxic resistance training (IHRT) has no effect on force-velocity, isometric strength, and muscle architecture [2][22].

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Swimming exercise at sea level causes a transient decrease in lung using the capacity for carbon monoxide[3]. The diffusion capacity for carbon monoxide describes the conductance of gas from the alveolar air to the capillaries and provides a measure of gas transfer in the lungs [12]. Exposure to hypobaric hypoxia can affect lung gas exchange, and hypoxic pulmonary vasoconstriction may elicit pulmonary edema [12]. Altitude exposure can be an added physiological challenge to the pulmonary system, raising the susceptibility to pulmonary edema in combination with exercise, water immersion, and hypoxia [21]. For non-athlete, exercise intensities [55–65% of maximal O2 uptake (VO2max)/60–70% of maximal heart rate (HRmax)] and similar levels of simulated altitude (~2,600 m) seems to be a best exercise prescription [16].

Physiological Changes

The primary adaptive responses athletes seek during altitude sojourns include the erythropoietin (EPO)-driven increase in red blood cells (or hemoglobin mass (HBmass) [29] [15] primarily. Improvement in the oxygen transport function of the blood, which is considered to be the main and the most common positive effect of moderate-altitude training, occurs for an elite athlete who trained for several months using the Live Low Train High (LLTH) method [23]. The significant finding of the present study was that 12 days short period of LHTH training camp at a low altitude (1850m) resulted in increased erythropoietin activity [15]. Exercise at hypoxia failed to elicit acute functional improvements in the pulmonary system in adults, suggesting that functional plasticity of the ventilatory muscles is limited in adulthood [12].

Modified motor unit recruitment patterns due to an increased anaerobic metabolism could also be partly responsible for the improvements [4]. Hypoxia-induced changes in motor unit recruitment patterns could affect the neuromuscular responses following resistance training [22]. In addition, an increase in spinal excitability has been related to acute simulated hypoxia, and a more significant increase in the Hoffmann's reflex amplitude of the soleus muscle has been described at acute moderate altitude compared to sea level [1].

Acute passive effect for non-athlete blood pressure, body weights range from 1 to 4 weeks remained unchanged [5]. Further improvements in metabolic markers such as triglycerides, total cholesterol, and HDL with HC would require the intervention of more than four weeks in duration for positive effects [16]. Nevertheless, other studies suggest that passive hypoxic conditions may be an effective modality to induce a shift in fuel utilization and expend a greater quantity of lipid-based energy stores [6]. Over a longer duration, this may lead to a substantially consistent negative energy balance that may promote measurable weight loss. Reductions in weight, BMI, and individual tissue mass are found following active hypoxic condition (moderate-intensity cardio-based exercise, three sessions per week, 4–8 week duration) [16]. The increases were most significant for individuals with pre-existing hypertension and obesity. There were no observed life-threatening cardiovascular events for participants. We conclude that for individuals with a modestly controlled blood pressure of 160/95 mmHg, hiking at a moderate altitude is a safe activity [30]

Hypoxia or al Altitude Training

Exposure to normobaric hypoxia or simulated altitude via a reduced inspired O2 fraction (FIO2) is increasingly popular as the number of commercially available devices permitting simulated hypoxic exposure is growing [7]. Primarily, this intervention allows living at or near sea level and then periodically exposing individuals to hypoxic conditions at rest or during exercise [8]. This is typically accomplished by breathing through a mask or staying in an environmentally controlled chamber/room/tent whereby the FIO2 is typically reduced to 15.0–12.0% (equivalent to simulated altitudes of ~2,600– 4,300 m) [16]. Positive changes might not be related to an additional effect of natural hypoxia [23].

These positive adaptations include increased basal noradrenaline levels, arteriole diameter, peripheral vasodilation, mitochondria number, glycolytic enzyme activity, insulin sensitivity, reduced diastolic blood pressure, and leptin levels [9]. Such physiological adaptations would, in turn, improve the metabolic phenotype of obese individuals [16]. The possible additive effect between air pressure and composition could positively affect explosive actions performed at moderate altitude, while simulated hypoxia does not display changes of interest and may reproduce different responses [1].

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CONCLUSION

The improvement of athletic performance, to a large extent, depends on the knowledge and experience of coaches and the ability of athletes to estimate their state and adjust training loads according to their condition [23]. The most significant positive changes are observed in athletes whose adaptation to the conditions of the medium-height mountains is accompanied by a moderate intensity of regulatory mechanisms and prevalence of the vagotonic type of autonomic homeostasis [27]

Physiologically, structural and functional properties of the lung and airways do not change in response to training in land-based sports. Training at altitude leads to enhanced total hemoglobin mass, erythropoietin volume, red cell volume, muscle buffering capacity, capillary density, maximal aerobic capacity, exercise capacity, and exercise economy [15]

Passive hypoxic condition protocols in humans may not be beneficial to improving cardio-metabolic health (reducing blood pressure) or losing weight [16]. The optimal effect can be found while training in altitude camp [23]

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