Effects of Cross-Training
Transfer of Training Effects on $\text{VO}_{2\text{max}}$ between Cycling, Running and Swimming

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Summary

Cross-training is a widely used approach for structuring a training programme to improve competitive performance in a specific sport by training in a variety of sports. Despite numerous anecdotal reports claiming benefits for cross-training, very few scientific studies have investigated this particular type of training. It appears that some transfer of training effects on maximum oxygen uptake ($\text{VO}_{2\text{max}}$) exists from one mode to another. The nonspecific training effects seem to be more noticeable when running is performed as a cross-training mode. Swimming training, however, may result in minimal transfer of training effects on $\text{VO}_{2\text{max}}$.

Cross-training effects never exceed those induced by the sport-specific training mode. The principles of specificity of training tend to have greater significance, especially for highly trained athletes. For the general population, cross-training may be highly beneficial in terms of overall fitness. Similarly, cross-training may be an appropriate supplement during rehabilitation periods from physical injury and during periods of overtraining or psychological fatigue.

Cross-training has received enormous attention since the triathlon has become a popular sport. One of the primary reasons for the growing popularity of cross-training is that a multi-sports activity is more enjoyable and breaks the boredom that often results from long term participation in a single sport. In recent years, this type of training has become a widely used protocol for structuring total training programmes for athletes of various specialities. In competitive endurance sports,
cross-training is usually intended to improve competitive performance in a specific sport by participation in other sports. It has become common for long-distance runners to supplement their daily training with cycling and swimming. Similarly, an increasing number of road cyclists are performing strength training and/or cross-country skiing, especially in the off-season. There is abundant anecdotal evidence indicating that cross-training may be beneficial to competitive athletes. In addition, it has been reported that VO$_2$max values of triathletes, measured in each sport, is comparable to that of athletes specialising in a single sport. Cross-training has now become one of the major components in the total training programmes for endurance athletes.

Despite the fact that cross-training is not a new approach for improving sport performance, scientific studies on the transfer of training effects are sparse. Based on the principles of specificity of training, the additive effects of cross-training have been questioned. Presently, it remains uncertain whether cross-training is beneficial for competitive endurance athletes and the lack of scientific research may be due to the difficulty in convincing competitive athletes to redesign their training programmes.

There has been no agreement about the definition of cross-training. Cross-training can be defined as simultaneous training for 2 or more sports. It can also be defined as a cross-transfer of training effects from one sport to another. Alternatively, some refer to cross-training as the conveyance of training effects from one limb to the contralateral or ipsilateral limb.

In this review, cross-training is defined as the transfer of training effects gained in one mode of training to another. The effects of multi-sports training programmes on VO$_2$max are considered. Concurrent training for 2 endurance activities is reviewed since it is one of the approaches used to investigate the compatibility of different training modes. The primary focus is placed upon running, cycling and swimming, because these 3 endurance exercises are most commonly integrated into the cross-training regimen.

1. Specificity of Training

Two of the most important principles for exercise training are overload and specificity. According to the principle of specificity, exercise training should simulate, as closely as possible, the conditions of a specific sport to elicit the greatest physiological adaptations. Therefore, one of the strongest arguments against the concept of cross-training is the principle of specificity of training. Since cross-training is a form of nonspecific training, a significant issue is whether crossover benefits of training occur from such training. Specificity of training can be applied to almost all the parameters involved in adaptive responses to exercise training, such as exercise modes, contraction velocity and contraction types. The external aspects of specificity of training are also evident internally in subcellular adaptations, i.e. adaptations within the muscle depend on the specific training.

Training programmes should be designed to simulate the mode of exercise normally undertaken by the athlete. As will be discussed, each mode of exercise (such as running, cycling and swimming) results in unique training adaptations. As can be seen in table 1, endurance athletes usually exhibit highest values of VO$_2$max when tested in their specific sport. This trend becomes evident when single-sport athletes are compared with reference groups such as untrained individuals and triathletes (table 1). Specificity of training is also an important consideration for the acquisition of skill, since involvement in a specific sport produces improvement in the coordination of specific muscle groups. It should be noted that even within a particular mode of training, some training conditions, such as posture (e.g. upright vs supine cycling) and training terrain (e.g. inclined vs horizontal treadmill) result in specific adaptations.