Allocation of playing time within team sports – a problem for discussion

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ABSTRACT
The background of the article is the recurrent discussion about allocation of playing time in team sports involving children and young athletes. The objective is to analyse why playing time is a topic for discussion among parents, coaches and athletes. The following question is addressed: Under which condition is it ‘fair’ to use equal and under which condition ‘fair’ to use unequal playing time? Methodologically the article combines literature in the field of psychology, physiology and sociology – and simple mathematics is applied in developing a model for estimating playing time, frequency and timing of substitutions. The article shows that team sports are arenas where social interaction takes place, where norms and rules are internalized and where allocation of a given playing time implies inclusion and exclusion of individuals. The article shows that there exists a single, objective ‘unfair’ allocation of playing time, but a variety of ‘fair’. Lack of objective criteria drives the discussion of fair allocation of playing time. A policy implication of the findings is that an insight into psychosocial mechanisms can change practice to obtain a better and sustainable organization of team sports where young athletes are involved.

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Introduction

The research subject is ‘young athletes’ involved in a game or competitive, social context. The article defines ‘young athletes’ as members of the age group from about 6 to 16 years, and the group includes pupils in primary, secondary and the first part of high school. The article is a partial analysis and focuses on the potential psychosocial effects involved in organizing team sports in the continuum of teaching and learning versus competition and winning. The research and scientific profile of the article is based on literature review addressing the subject, and application of relevant international literature in the field of psychology, physiology and sociology. The article also applies simple mathematics in developing an analytical model for estimating playing time, frequency and timing of substitutions.

Playing time in team sports where children and young athletes are involved is a topic for discussion among parents, coaches and teachers (see, for example, Choosing to Grow,
Although the topic seems to be a universal phenomenon, it is barely discussed in the academic literature. In team sports such as American and English football, rugby, handball, volleyball, basketball and others, the number of players actively taking part in the game is given by the rules of the game. Most of the games have a fixed game-time. Volleyball is an example of a game that has a fixed number of players but no time limit. It is likely that the tug of war of playing time starts from the following context: Normally, the number of athletes in the team is larger than the number of players allowed to take part in the game. From this it follows that some of the players have to start on the bench as substitutes. But who are likely to be selected as substitutes, and for how long are the athletes going to sit on the bench waiting to enter the game? Although the described situation looks quite simple and easy to solve as a decision problem, we will in the following go deeper into the problem and ‘prove’ that there are important and controversial aspects involved in it.

Trainers, teachers and coaches experience conflicts and dilemmas in connection to organizing matches with substitutes. On the one hand, the team leaders wonder how they can organize the team so that it is inclusive and fair, for example by letting each player participate an equal amount of time, or in the case of winning the contest, there is a strong incentive to give more playing time to the best athletes at the expense of players with less capacity. If the coach chooses the second option, then they have to perform a value judgment, rank players and exclude some from taking part in the game. See Hsu (2004) who analyses moral conflicts in sport and Wang and Callahan (1997) who analyse the psychological effects of being a substitute player at a high-school level. Some players may feel unfairly treated, especially if it is not obvious who might be the best. The situation can initiate destructive, internal conflicts that can be counterproductive and interfere with teaching and competitive success (Anker, 2010).

Additional questions follow: Does fair allocation of playing time necessarily imply equal sharing of playing time? Are there objective criteria that can be applied in finding a fair allocation of time between the athletes?

Literature review shows that the topic is barely discussed among academics in sports. ‘Fairness’ is on the other hand studied by other disciplines. In the field of behaviour economics, Fehr and Schmidt (1999) analyse fair allocation of income, and in the field of social psychology Leventhal (1980) study perceptions of fairness in social situations. The limited part of the sport science literature which addresses the topic indicates that the way playing time is allocated between players has an effect on motivation and the psychosocial environment. For example, team spirit and friendship among team members may be compromised (Eys et al., 2013; Gréhaigne, 2011; Ommundsen, Roberts, Lemyre, & Miller, 2005). Sports involve social interaction between people, and the content and quality of the interaction shape the value system of young participants. Bailey (2002, p. 163) argues that all kinds of play are a ‘…fundamental medium for acquiring social skills’. From this it follows that the ways team sports are organized, often controlled by the coach, club and federation, have potential implications for how and what type of norms and values young athletes internalize.

The rest of the article is structured in the following way. The next section presents an evaluation of the derived mathematical model for equal playing time. The motivation for presenting the model is threefold. Firstly, the model shows how playing time and frequency of substitution can be formally calculated, secondly the model can be applied
in schools and clubs and thirdly that the model is related to sections which follows. The model is in detail presented in Appendix. Thereafter, we go deeper into the topic and analyse how allocation of playing time is influenced by the value system in clubs and among coaches, and how distribution of playing time affects motivation and the psychosocial environment. The last section concludes the article.

**Evaluation of the model**

The formal derivation of the model is presented in Appendix. One of the objectives of the article is to derive a model which can be used in practice, where team leaders or teachers and involved athletes can easily estimate how many times each player has to be substituted, the playing time, and the frequency and timing of substitutions. The derivation of the model shows that the complexity of the effective playing time for each player and frequency of substitutions are critically conditioned on the numerical relationship between the numbers of players \( M \) and substitutes \( N \). We show that sharing the playing time is easiest when the numbers of players \( M \) and substitutes \( N \) have a common scaling factor or when the ratio between \( M/N \) is an integer. The model can also be applied in situations where the team prefers differentiating the allocation of playing time between the athletes. An alternative is to allow one or more of the selected athletes to play the whole match and share equally the remaining part of the total playing time between the rest of the players. This way of organizing the team can protect against demotivation caused by too many substitutions that can have negative impact on the performance of the team independent of level of skills. Another alternative is to use weights in the allocation of playing time between the athletes. The size of the weights reveals the preferences the team has with regard to allocation of playing time between the members, or in other words – the size of the weights reflects for example the skilfulness and competitiveness of the athlete, that is, the larger the weights, the more competitive and the more playing time is allocated to the athlete. However, it is complicated to derive weights that can be applied in practice. When we observe as a fact that playing time is not uniformly distributed it confirms that the coach is using an implicit weighting system. Sometimes these weights or priorities are not discussed openly or lack legitimacy, and can thus be a source of conflict. In practice, the allocation of playing time is obviously not always pure calculation. In the following, we will look into these aspects more closely, and the objective is to better understand why allocation of playing time is a topic for discussion.

**The incentives and value system in teams**

What is ‘fair’ allocation of playing time? It is complicated to define clearly what ‘fair’ allocation of playing time means. It is a value judgment and one or more criteria have to be applied, and we also assume that there is consensus in the group about the criteria of ‘fairness’ which leads to and maintain a sort of stable social equilibrium between the parties. ‘Equal’ playing time is far easier to define because it is not an abstract entity. It is a mathematical expression that can be operationalized as the derived model shows (see Appendix). But there is as well a value judgment – a set of criteria – involved in the decision of applying equal playing time in practice, and equal playing time could be interpreted as
unfair. We will analyse some of these arguments and value judgments in the article. With regard to the derived mathematical model, it is also an intention to show that there is a link between the theoretical model of equal playing time and certain characteristics of reality.

To simplify the discussion about playing time, we use two different idealized types of organizing teams. The first team is performance-oriented, selective and focusing on using athletes who have the best skills, perform on high level, being competitive and focus on winning. The second idealized type of team is mastery-oriented which typically looks upon sport activity as a learning process, the team does not differentiate between athletes, the activity is based on egalitarian principles and everybody plays an equal amount of time independent of whether the athletes have different skills. The process or mastery-oriented work in sports focuses on developing the social and physiological skills of young athletes (Phillips, 1997; Wilson & Khoo, 2013).

The performance-oriented clubs reveal strong preferences for being as competitive as possible. But to be the best – to be on the podium, requires that the most skilful athletes are playing. It follows from these preferences that the less skilful athletes are playing a limited amount of time compared to the group of more skilled athletes. It is likely that a strong preference for being the most competitive team leads to a selection process where the less skilled athletes end up as permanent substitutes. The allocation of time is differentiated among athletes in performance and winning-oriented clubs that are typical for professional clubs (Thiel & Mayer, 2009).

The dualism between being a mastery-oriented and inclusive versus being performance or winning-oriented and exclusive is discussed by Gerber (1999). How the organizations or institutions combine and prioritize the characteristics seems to be conditioned on culture, traditions and formal regulations. In the field of organizational theory, Edquist (2005) shows how norms and informal rules regulate the behaviour of a person. If there is a lack of objective criteria on how to prioritize between these two dimensions, there is an element of relativism between the value standards the teams or coaches use when they allocate playing time between athletes. Ommundsen, Roberts, Lemyre, and Treasure (2003) show that the psychosocial environment (norm system) differs between performance and mastery-oriented teams, and that the difference has a significant influence on the degree of social-moral reasoning, attitude to antisocial behaviour and sportsmanship. Anker (2010) applies different sophisticated moral philosophical perspectives from Rawls (2001), Sen (1999), MacIntyre (1985), Benhabib (1992) and Nussbaum (2005) in analysing how to share fairly the playing time, but without finding any clear solution.

Equally skilled team members make it easier

It follows necessarily that the allocation of playing time is less a topic for discussion and not a source of an internal conflict if the athletes on the team are equally skilled and perform equally. This is a priori the most robust situation against conflicts related to allocation of playing time, because the performance of the team is maximized if playing time is allocated equally. We can conclude that independent of whether the team is result or mastery-oriented, the equal playing time model is the rational way of allocating playing time when the athletes have similar physical and psychological skills. Given these conditions, equal playing time is identical with fair allocation. The conclusion follows with necessity because when athletes
are equally skilled it is not possible to realize any gain or an advantage by reallocating or differentiating the playing time between the players. This is a theoretical argument. In practice, the athletes are differently endowed physiologically and psychologically. The point is that the more similar they are, the more relevant it is to use the equal playing time model. Ommundsen et al. (2005) show that these objectives are easier to fulfil if the team consists of equals compared to a team where the spread of skills is large and opinions diverge.

Unequally skilled members – present challenges

Teams that consist of athletes who differ with respect to skills and in addition are focussing primarily on being the most competitive, can be unstable and experience conflicts with regard to allocation of playing time (Goldstein & Iso-Ahola, 2006). Let us look closer into the arguments behind the proposition. Large differences in skills and high expectation for being competitive is a combination that is likely to polarize a team, that is, a process which gradually drives a wedge between those who fulfil the criteria and those who do not. A situation like this is expected to impose pressure on the team to use the most skilful athletes and the result is an unequal allocation of playing time. These preferences contribute to less playing time for athletes who are on a lower level. In the long term it is likely that these players can feel that they no longer are appreciated members of the team and it represents a feedback effect which demotivates this group of athletes (Lidor, Arnon, Maayan, Gershon, & Côté, 2014; Wang & Callahan, 1997).

The larger the spread of skills between the team members, the stronger the effect of selection and exclusion. It is expected that this is the dominant strategy in a competitive context. It is a clear equivalence to economic thinking, in the meaning that economic resources are allocated where the expected profits are highest or that the most productive resources are first exploited. The effect of putting too much emphasis on competitiveness, or exaggerating the objective of being the best team, can result in a loss of young athletes whose potential is not fully developed (Waldron, Worsfold, Twist, & Lamb, 2014; Wattie et al., 2014). These athletes could have developed in a different way if the organization and value system of the team was more inclusive and mastery-oriented rather than performance-oriented (Augste & Lames, 2011). The organization of the team and its profile are influenced by the time-preferences characterizing the influential decision makers in the team, their value system, the social status of winning and the cost of losing. These subtle effects can have negative impacts. The literature shows that too much emphasis on performance and winning in entry-level teams can lead to sub-optimal development of athletes whose potential is not fully realized, and in that respect a one-sided performance-oriented strategy can be sub-optimal in the long run.

Sports and internalization of norms

Let us look into the following proposition: The philosophy behind equal playing time and the derived model are more important the younger the athletes are. The argument is that younger athletes are more sensitive than older athletes and they are in addition in a learning process. The argument for sharing the playing time more equally is that young people are not fully developed physiologically, psychologically and socially, and, in addition, the spread in the level of development between young athletes of the same age is higher
compared to older athletes. This is accordance to behaviourism and psychologically based evolution theories. See, for example, the classical work by Allport (1962), Erikson (1960) and Tolman (1932) which support the arguments. Wilson (1999) and Lidor et al. (2014) show how the so-called birthdate-effect influences the playing time in school sports teams. The younger the athletes are, the more they have to learn to be good and skilled athletes (Holt, Ward, & Wallhead, 2006). Butler (2000) and Rudd and Stoll (1998) show in interesting articles how an athlete’s character and sportsmanship (fairness, respectfulness, courteousness and generousness) are a result of learning and the role a coach or teacher has in this process. Gibbons, Ebbeck, and Weiss (1995) used stratified samples in analysing the effects on the moral development of children in physical education. Youell (2008) and Vidoni and Ward (2009) describe the long-term learning process for becoming an integrated person in society.

Organizations and institutions play an important role in the internalization of norms and social values. Federations of sports in most countries devote resources to mastery-oriented sports programmes for young athletes. These programmes develop discipline, team spirit and pleasure in team success. According to Willis (2000), the broader the view we impose on sports and the younger the athletes are, the more influence sports and coaching have on the socialization process. See, for example, Apostolou (2015), who applies an evolutionary perspective on the role sports have among people. Combeau-Mari (2011) shows in a broader sense the role sports play in the French education system after 1949, and Bergsgard and Norberg (2010) analyse the sport policy in the Scandinavian countries. Hardman, Jones, and Jones (2010) show the influence a coach has with respect to building social competence (respect for other people, fairness and self-esteem) of young athletes, and Ommundsen et al. (2003) conclude that coaches influence on the motivation and psychosocial environment for young athletes. Horn (1986) draws a similar conclusion many years before Ommundsen et al. (2003), which confirms the validity of the conclusion. According to the Norwegian Federation of Sports, with regard to activities involving children 12 years old and younger, all sports should be practiced without any form of discrimination (Norwegian Federation of Sports, 2014). Sweden and Denmark follow similar rules (Danish Federation of Sports, 2014; Swedish Federation of Sports, 2014). These values are especially aimed at the target age groups up to about 12–13 years. After this age-level, athletes are gradually becoming more mature and teams are free to prioritize competition and rank athletes according to the skills and performance level.

Discussion and conclusion

The background of the article is the recurrent discussion about sharing playing time in team sports where young athletes are involved. The main objective is to analyse why playing time is a topic for discussion among parents, coaches and athletes. The article addresses the following question: Under which condition is it ‘fair’ to use equal and under which condition is it ‘fair’ to use unequal playing time? Methodologically, the article combines international literature in the field of psychology, physiology and sociology – simple mathematics is applied in developing an analytical model for estimating playing time, frequency and timing of substitutions. In the following, we will present and discuss the main results of the analysis.
The article derives a model that can be applied in calculating playing time in team sports. The team leader or teacher can estimate the frequency and timing of substitutions. The model shows the complexity of calculating these entities and that they are critically conditioned on the numerical relationship between numbers of players and substitutes. The analytical model is neutral in itself, but the decision behind using the model is based on value judgements which are discussed in the article. The article shows that the more equally the athletes are treated and/or the more equally the athletes are with respect to skills, the more suitable the analytical model is for calculating playing time.

The article shows that the most robust and clear conclusion that can be drawn from the analysis is that equal playing time is *rational* to choose and the dominant model to use in practice when the athletes are equally skilled. Given the assumption, equally sharing of playing time is actually immune against conflicts and discussions. It follows from the analysis that it is *irrational*, and also a source to conflicts and discussion, to allocating the playing time unequally if the athletes are equally skilled. We can therefore exclude the last combination as irrelevant and not a likely team profile.

The article shows in addition two more team-profiles. The first one is a team profile that is a combination between performance-orientation and unequally skilled athletes. The combination is expected to exclude equally sharing of playing time because equally sharing of playing time does not maximize the likelihood of winning – or equivalently, it does not minimize the social cost of losing. The second model is a team profile that is a combination between a mastery-oriented organization with unequally skilled athletes. The profile of the team is clear, but the distribution of playing time is ‘open’, which implies that the allocation of playing time is conditioned on a set of factors influenced by social norms of the decision makers, the social environment, scientifically based arguments, etc. When the allocation of playing time is ‘open’, it includes the outcome that the playing time is equal. It could even imply that players with lack of skills are prioritized and allocated a larger share of the playing time compared to the skilled.

The article shows that equal playing time is rational to apply given that the athletes are identical, and the allocation is independent whether the profile of the team is mastery or performance-oriented. Although it seems rational to draw the conclusion that a performance-oriented team should differentiate in the allocation of playing time, the article shows clearly that this strategy is associated with social and psychological effects which have to be taken into account when evaluating – or discussing – how to share the playing time in team sports. An important conclusion that can be drawn from the analysis is that the younger the athletes are, the higher is the likelihood of realizing negative side effects of applying a performance-oriented profile. The ensemble of subtle psychological and social effects and the conflict of interest against performance and winning could be an explanation why sharing of playing time is a topic for discussion.

The following question is formulated in the introduction of the article: Under which condition is it ‘fair’ to use equal and unequal playing time, respectively? Is it possible to say anything about ‘fair’ allocation of playing time, given the discussion in the article? It is self-evident that it is not fair to differentiate the allocation of playing time if the athletes are equally skilled. But, does it imply that it is fair to differentiate the playing time if the athletes are endowed with different skills? The answer could be ‘yes’ – but not unconditionally ‘yes’. Games and team sports are essentially, by nature so to speak, about competition and in that respect it implies, like a lock-in-strategy or binding commitment, that the
team has to use the best athletes in order to maximize the likelihood of winning the game. Given this context, it is rational that the team is performance-oriented, and selective in allocation of playing time. But the article shows that there are likely negative effects associated with applying the performance-oriented model in organizing sports where youngsters are involved. The potential psychological and social costs – or negative side effects, which are highlighted in the article, indicate clearly that the performance-oriented model has to take into consideration the side effects when differentiating the allocating of the playing time. Internalization of likely short and long-term feedback effects in the wake of an exaggeration of the performance-oriented team model implies an adjustment towards the mastery-oriented profile and relative more sharing of playing time among the players. However, still we cannot identify any objective criteria with regard to the relative weighting of these two models of sharing playing time, except, as the article shows, that the younger the athletes are, the more equally should the playing time be allocated. In real life the teams are a mixture of these models. The unclear criteria open up for cultural relativism which implies that local or regional set of social values determine the allocation playing time and the weighting between how much a team is performance and mastery-oriented.

In general terms, in order to obtain consensus on the interpretation of ‘fair’ allocation of playing time the involved parties must share the same norm or value system. If the objective is to be the winning team, it is fair or rational to allocate the playing time to the best players. We conclude that fair allocation of playing time does not necessarily imply equal sharing of playing time. Linked to norms and arguments, people distinguish between fair and unfair unequal allocation of playing time.

The article shows that organizing and performing sports where youngsters are involved is a complex transformation process, and it follows that ‘fairness’ should be discussed in a broader context. Young athletes evolve physiologically and psychologically in stages, from immature to mature and the development in stages has implications for how to organize team sports. We conclude that a gradual transition from a mastery-oriented organization of young athletes to a performance-oriented organization which focuses more and more on competition and ranking of players is consistent with regard to how young athletes evolve physiologically and psychologically. An important finding is that equal allocation of playing time is a part of the mastery-oriented model of learning, and we conclude that equal playing time is still important to practice – especially with regard to the younger age groups. One way to start solving the recurrent discussion of playing time is that federations of sports and clubs explicitly operate with organizational guidelines and rules that correspond with the level of development of the athletes.

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Appendix

Allocation of equal playing time in team sports

The objective of Appendix is to derive a model that helps coaches and teachers to calculate equal playing time, frequency and timing of substitutions, and to identify combinations of players and substitutes which make it difficult to organize equal playing time. The model can be applied as a part of the education and teaching in school. The model is only valid to use in sports where the playing time is fixed, that is, in football, handball, basketball, ice and land hockey, and rugby. The derived model is not applicable in, for example, volleyball, where the playing time is not fixed unless the organizers regulate the match or training by imposing a time-restriction.

Let us start with a theoretical assumption that is not likely to be fulfilled in real life. Assume that the players are equally skilled and perform identically. Because of the similarities the coach does not need to make strategic priorities with respect to selecting who is going to play or will be a substitute. The players who are going to start are selected randomly, which could be interpreted as a gesture of fairness. Assume that the team has $M$ players and $N$ substitutes. The team therefore has $L = M + N$ athletes who can take part in the game.

Examples: $M = 3$ implies that there are allowed to use three players. Football requires $M = 11$. Basketball requires five players, that is, $M = 5$. Assume that a single round of a match lasts $t_0$ minutes (or seconds). The team’s total or aggregated time of playing is expressed as

$$ T = t_0 M. \tag{1} $$

Each athlete takes part in the game $M$ times during the period $t_0$. And each time the athlete actively participates in the game, the playing time is $t_0(M + N)^{-1}$. It follows that the accumulated time each athlete is playing per round is

$$ t_A = \frac{t_0 M}{M + N}. \tag{2} $$

Analogously, each athlete is a substitute $N$ times during the match and the accumulated time the player is a substitute can be expressed in the following way:

$$ t_S = t_0 - t_A = t_0 \left[ 1 - \frac{M}{M + N} \right] = \frac{t_0 N}{M + N}. \tag{3} $$

Each time the player is a substitute, the athlete is out of the game for $t_0(N(M + N)^{-1}$ time units. The total number of substitutions made by the team is

$$ S = M + N - 1, \tag{4} $$
given that the game starts with the first $M$ players. The first substitution of players takes place at time point $t_0(M + N)^{-1}$, the second substitution of players takes place at time point $2t_0(M + N)^{-1}$,
etc. and the last substitution takes place at time point \((M + N - 1)t_0(M + N)^{-1}\). By combining these equations, it is possible to estimate the total playing time per player and the total time as a substitute per round per player. The application of the model will be demonstrated in the last part of Appendix.

**Ease of model application depends on M and N**

In the case of maximum training and experience for each team member, we have argued that each athlete should take part in the game \(M\) times and sit as a substitute \(N\) times. The critical conditions are delineated by the following four remarks.

**Remark 1**: The value of \(M\) and the total playing time \(t_0\) are given by the rules and the value of \(N\) is assumed not restricted. Suppose \(M > N\). The values of \(M\) and \(N\) determine whether it is possible to factorize the numbers by a common factor or whether the fraction between \(M\) and \(N\) is an integer, that is, a number without a fractional component.

If it is possible to simplify the fraction \(M/N\) by a common factor, the simplified numbers are used in the equations. **Example**: If \(M = 10\) and \(N = 4\), \(N < M\) and \(M/N = 10/4\). The common or shared factor of the numerator and denominator is 2, and by simplifying we get

\[
\frac{M^*}{N^*} = \frac{10/2}{4/2} = \frac{5}{2},
\]

which implies that the minimum number of substitutions is: \(S = M^* + N^* - 1 = 5 + 2 - 1 = 6\) times. It follows that each athlete plays five times and stays as a substitute two times per round \(t_0\). Note that the modified numbers \(M^*\) and \(N^*\) are used as input values in Equations (1)–(4). The situation where \(M\) and \(N\) have no common factor can be frustrating for coaches. For example, when playing for example football: \(M = 11\) and \(N = 5\). The total number of substitutions is \(S = 11 + 5 - 1 = 15\) which implies a rather high frequency of substitutions. No common factor can reduce the dimension of the problem. This is the minimum number of substitutions, given a firm commitment to equal playing time. From a mathematical point of view, it is possible to give each player equal playing time per period, but this may be rather impractical.

We have not discussed a situation where the number of substitutes \(N\) is larger than the number of players \(M\), that is, \(N > M\). The calculation of the amount and number of time each athlete is playing and number of substitutions is calculated in the same way as when \(M > N\). Factorization of \(M\) and \(N\) is done in the same way.

**Remark 2**: If \(M = N\), the ratio is one, which implies that the number of substitution (5) is one, and the playing time for each athlete is

\[
t_A = \frac{t_0M}{(M + N)} = \frac{t_0}{2}.
\]

When \(M = N\) each player in the team plays half of one round – or alternatively plays one round and rests on the bench during the next round.

**Remark 3**: Let us see what happens when \(M \geq N\) and the ratio \(M/N\) is an integer \(a\), that is,

\[
\frac{M}{N} = \alpha,
\]

where \(\alpha = 1, 2, 3, \text{etc.}\) The number \(\alpha\) is a measure of the total number of substitutions the coach has to make during \(t_0\). This implies that each athlete is only a substitute once during \(t_0\). The total time each athlete plays can be expressed in the following way:

\[
t_e = \left\lfloor \frac{\alpha}{\alpha + 1} \right\rfloor t_0.
\]
The time each athlete is a substitute can be expressed as

$$t_S = \left\lfloor \frac{1}{\alpha + 1} \right\rfloor t_0.$$  \hspace{1cm} (9)

The coach substitutes at the following time points; $t_0(\alpha + 1)^{-1}$, $2t_0(\alpha + 1)^{-1}$, \ldots, $\alpha t_0(\alpha + 1)^{-1}$.

**Remark 4:** Note the following when the number of substitutes is larger than the number of players, that is, a situation where $N > M$ and ratio $N/M$ is an integer $\beta$, indicating multiple complete teams. In this situation where $N/M = \beta$ and $\beta > 1$ each athlete plays only once during $t_0$. The integer $\beta = 1, 2, \ldots$, etc. represents the number of sub-teams that can be derived from the ‘main’ team, of size $M + N$. The time each player actively participates in the game can be expressed as $t_A = t_0(\beta + 1)^{-1}$.

**Application of the model**

A single round of soccer lasts 45 minutes. The number of players is $M = 10$, given that the goalkeeper is not substituted, and assume that the number of substitutes is $N = 5$. The ratio between $M$ and $N$ is an integer: $M/N = a = 2$. According to Equation (6), $a = 2$ which implies that there are two substitutions during the time-period $t_0 = 45$ minutes. When the ratio between $M$ and $N$ is an integer, the model predicts that each player is substituted only once during the period $t_0$. The time each athlete is on the pitch is $t_0(\alpha + 1)^{-1} = 45(2 + 1)^{-1}2 = 30$ minutes, and the time spent as a substitute is $t_0(\alpha + 1)^{-1} = 45(2 + 1)^{-1} = 15$ minutes. The first substitution takes place after $t_0(\alpha + 1)^{-1} = 15$ minutes after the match has started, and the second substitution takes place at $2t_0(\alpha + 1)^{-1} = 30$ minutes. The example shows that it is easy to organize the allocation of playing time and substitutions when the relation between $M$ and $N$ is an integer. Mathematically, fair substitution is more difficult when the ratio between $M$ and $N$ is not an integer and even worse if the $M$ and $N$ have no common factor. Let us say the goalkeeper is treated as the other players. It implies that $M = 11$ and $N = 5$. In this situation, it is not possible to factorize because $M$ and $N$ do not share any common factor. To be able to solve the problem, we have to use Equations (1)–(4) without any modifications of $M$ and $N$. The number of times each athlete is taking part in the game is $M = 11$. The total number of substitutions is $S = M + N - 1 = 15$, and the number of times each athlete is a substitute is $N = 5$. As we can see from this last example, it must be frustrating and in practice difficult for the coach or teacher to fulfill the objective of allocating equal playing time to each member of the team. One way to solve the problem is to impose a restriction. For example, by not substituting the goalkeeper which reduces the dimension of the problem to $M = 10$ and $N = 5$. This is a situation that we have shown is easier to organize.