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Original article

CONTROL PARAMETERS IN THE INSTRUCTION OF INDOOR CYCLING SESSION

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Abstract

Indoor cycling (IC) is a popular physical activity with several health and wellness benefits. However, to maximise these benefits and ensure the safety of participants, it is essential to control three key aspects: bike fit, pedalling cadence and session intensity. Proper bike fit is crucial to prevent injuries and ensure optimal performance. An all-fitting bike can lead to joint discomfort, especially in the knees and back. Cyclists must adjust the saddle height, handlebar position and handlebar spacing to suit their morphology. A saddle that is too high or too low can alter pedalling mechanics, while poorly positioned handlebars can cause strain on the shoulders and neck. Cadence refers to the speed at which the cyclist pedals, measured in revolutions per minute (rpm). Controlling cadence is important because it directly influences the type of training. A higher cadence is usually associated with more intense cardiovascular work, while a lower cadence may focus on developing muscular strength. Instructors should teach participants to find their optimal cadence and to vary it during the class to work with different energy systems. In addition, maintaining an appropriate cadence helps improve pedalling efficiency and reduces the risk of premature fatigue. Exercise intensity is another critical factor in indoor cycling. Intensity can be adjusted by changing the bike's resistance and varying the pedalling pace. Controlling intensity allows participants to customise their training to their individual goals. Instructors should be able to guide riders in perceiving their effort (e.g., using scales such as the Borg) and adjust their resistance level to reach their goals without compromising their safety. In short, controlling bike fit, pedalling cadence and intensity during an indoor cycling session is essential to ensure a safe and effective experience. These elements prevent injury, optimise physical performance, and enable participants to achieve their personal goals.

Keywords: Indoor cycling, safety, control, settings, cadence, intensity.

Introduction

Indoor cycling (IC) is defined as a high-intensity, cardiovascular physical activity, normally performed in groups, that also works lower limb muscle strength, on a stationary bike, to the rhythm of music and led by a highly trained instructor (Chavarrias et al., 2019). Scientific studies show that IC training has a positive impact on improving cardiovascular and respiratory health, decreasing adipose tissue and reducing the risk of cardiovascular disease (Bianco et al., 2010; López-Miñarro & Muyor Rodríguez, 2010; do Valle et al., 2010; Vilarinho et al., 2009; Foster et al., 2006; do Valle et al., 2009).

However, the high intensity that can be reached in an IC session can cause the maintenance of very high training load values on a chronic basis or their maintenance over long training periods, together with an inadequate cycling position or inappropriate pedalling cadences, to lead to various injuries (Hulin et al., 2014; Tomabechi et al., 2021).

Due to these reasons and the fact that this activity is predominantly cardiovascular, working at the same time on the muscular strength of the lower limbs (Barbado Villalba, 2010), the instructors must be qualified professionals to guarantee the safety of the participants in terms of injury prevention, with technical knowledge in the biomechanics of exercise and in the design and effectiveness of the sessions (Estrada-Marcén et al., 2021).

Some muscular risks during cycling include fatigue, loss of muscle control, poor technique, or lack of physical preparation (Bianco et al., 2010). Some studies have analysed the cycling index to measure fatigue (de Melo dos Santos et al., 2017), adaptations (Hedman, Bjarnegård & Länne, 2017) and cardiovascular and metabolic response (Stöggl et al., 2016).

To ensure the safety of participants during the development of an IC session, three key aspects must be taken into account (Sánchez-Muñoz et al., 2023) which are: i) the correct adjustment of the bicycle according to the anthropometric characteristics of each subject; ii) the use of an appropriate pedalling technique and cadence, which allows correct

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alignment of the body and avoids injuries and; iii) constant monitoring of the intensity of the effort, adapting the resistance levels and cadence to the capabilities of each participant.

Through an exhaustive analysis of these variables in the studies used, we will seek to establish guidelines and protocols that will allow instructors and coaches to develop training sessions appropriately, under principles of safety without reducing the effectiveness of the activity.

Therefore, the main objective of this work is to determine the key variables that influence the three fundamental aspects mentioned above, minimising the risks associated with this activity.

1. BICYCLE ADJUSTMENT

The basic position on the bicycle is defined as the one that allows the best use of the capacity to generate force by the muscles involved in the pedalling gesture, as well as its transmission to the pedals (Bini, Hume, Croft, et al., 2014). The position on the bicycle will be determined fundamentally by two factors, the individual technique and the bicycle itself in terms of the measurements of its different segments having some relationship of proportionality; that is, a poor position of the cyclist can be seen on the one hand to an imbalance in the correct way of standing on the bicycle and, on the other hand, to inadequate adjustments in the basic elements of the bicycle, which would also result in a poor position during the pedalling gesture (Bini, Hume, & Croft, 2014).

Some studies have considered the motion and lateral forces generated during the pedal cycle to be undetectable and have analysed the kinematics of the knee in a frontal plane (Hull & Gonzalez, 2016). These studies have shown that it is necessary to measure knee moments of force outside the sagittal plane because of their relationship to the stress on the knee joint and their potential influence on injury (Ruby, Hull & Hawkins, 1992). In this way, normal pedalling supports more adduction (the knee is positioned between the pedal and the bicycle frame) than abduction (Ruby et al., 1992).

In contrast, the angular shape of the hip in the sagittal plane, which is determined by the relationship between the thigh and trunk segments, is difficult to compare studies, as it depends on saddle height and trunk flexion (Belluye & Cid, 2001) (determined by the grip on the handlebars). However, as the hip is the weakest joint of the lower limb during the pedalling cycle, its linear kinematics can be examined. There are differences in the behaviour of the hip axis (the greater trochanter of the femur) and, although some authors consider that this remains "virtually static," others indicate movements of greater amplitude (Hull & Gonzalez, 1988).

The most common injuries in cycling are due to joint overuse or a bad position on the bicycle and fundamentally with the position of the bicycle saddle (Noriega-González et al., 2023). We could highlight injuries such as iliotibial band syndrome common in cyclists who have a bad alignment of the knee or who incorrectly adjust the saddle height (Holmes, Pruitt & Whalen, 1993) or patellar tendinitis in the knee due to inflammation in the tendon that connects the patella to the tibia. At the lumbar level, incorrect posture during exercise can cause tension in the lower back and back muscles, so it is important to maintain good alignment and correctly adjust the handlebars and saddle to avoid this discomfort. On the other hand, overuse or poorly fitting shoes can cause inflammation of the Achilles tendon, which together with constant pressure on the feet can lead to this inflammation of the tissue that connects the heel to the toes producing plantar fasciitis.

On a muscular level, lower body muscles, especially the quadriceps, hamstrings, and calves, are prone to strains or cramps due to overexertion or lack of proper warm-up (Maughan & Shirreffs, 2019). A prolonged position on the handlebars can cause numbness or pain in the hands and wrists, known as carpal tunnel syndrome, so good handlebar height adjustment is important to help prevent this discomfort.

Bicycle saddle height is a topic that has no clear answer among different experts, but it is particularly important because it affects the proper movement of key joints such as the hip, knee, and ankle. In addition, the saddle setback, the distance between the vertical of the bottom bracket axle and the tip of the seat is also truly relevant (Priego-Quesada et al., 2024).

The saddle height is the main position parameter that determines the correct work to the knee and must allow a maximum extension of 150 to 155º, i.e., the knee must never be able to fully extend during the pedalling cycle, since if the passage of the foot through the lower dead centre of the leg were fully extended, this would mean that the quadriceps would be at its greatest possible degree of shortening and, therefore, its capacity to reproduce force would be lower (Peveler, 2008). Consequently, the saddle height should not be such that the leg is fully extended, as this can lead to problems with the hamstring musculature as well as goosefoot tendonitis or iliotibial band syndrome (Khaund & Flynn, 2005).

When sitting on the saddle and placing the metatarsal heads in the lowest pedal position, the knee should be slightly bent (25-30°). The hip should not move up or down when pedalling. If the saddle is too high, the cyclist may experience pain in the lower back and tension in the hamstrings. If the saddle is too low, (s)he may experience pain in the knees, lack of power when pedalling and tension in the hips.

When the saddle is too low, the knee flexes more during pedalling, resulting in increased strain on the patellar tendon (Wang et al., 2020), as well as increased gluteal involvement resulting in reduced pedalling efficiency. This, in turn, can lead to increased compression at the patellofemoral joint, resulting in accelerated wear of the cartilage between the patella and femur, a condition known as chondromalacia patellae (Wang et al., 2020; Menard et al., 2020; Tamborindeguy & Bini, 2011).

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To improve the effectiveness of the hip extensor muscles, especially the gluteus maximus, the distance between the saddle and the handlebars must be adequate (Bing et al., 2024). Therefore, determining the correct saddle position is crucial (McDonald, Holliday & Swart, 2022). When the saddle is set back, more power is obtained, but the pedalling cadence is reduced (Koutsilieris et al., 2024). Conversely, bringing the saddle forward favours the muscles involved in the second phase of the pedalling cycle, which allows higher cadences to be achieved (Husband et al., 2024). Similarly, specialists warn that pain in the front of the knee can also be associated with a saddle that is too far forward, while pain in the back of the knee is often determined by a saddle that is too high or too far back (Wang et al., 2020). This is due to the different angles and stresses generated in the knee joint depending on the position of the saddle (Bini et al., 2023).

Therefore, saddle height adjustment is one of the most essential elements to achieve correct positioning on the bicycle (Peveler, 2008). There are several methods recommended by experts to determine the optimal saddle height (Gámez et al., 2008):

- Crotch method (Figure 1): According to this method, the distance between the top of the saddle and the pedal at its lowest point should be equal to 109% of the cyclist's crotch measurement (Pedal-to-saddle distance (cm) = Crotch length (cm barefoot) x 1.09). This method is based on the length of the user's legs, if a distance equal to 109% of the crotch will allow adequate leg extension during pedalling (Millour et al., 2021).
- Greater trochanter method (Figure 1): This method states that the distance between the top of the saddle and the pedal at its lowest point should be equal to the distance between the ground and the greater trochanter (top of the femur) of the cyclist. This allows the leg to extend fully without locking the hip joint (Dhinsa et al., 2019).
- Ischial tuberosity method (Figure 1): According to this method, the distance between the top of the saddle and the pedal at its lowest point should be equal to 113% of the distance between the ground and the ischial tuberosity (bony prominence at the bottom of the pelvis) of the cyclist (Swart et al., 2019) (Pedal-saddle distance (cm) = Ischial tuberosity height (cm barefoot) x 1.13). This method considers the specific length of the segment between the ischial tuberosity and the pedal.

Figure 1. References for the different leg measurements: (a) ischial tuberosity; (b) trochanter-soleus distance; (c) crotch measurement (Bini, Hume & Croft, 2011)

- Lemond's method (LeMond & Gordis, 1987) (Figure 2): The three-time American Tour de France champion indicates that the relationship between crotch length and saddle position on a bicycle is a key factor in achieving a comfortable and efficient posture on a bicycle (Briceño et al., 2019). Numerous studies have determined that the optimal distance between the bottom bracket shell and the saddle is approximately 88.3% of the cyclist's crotch length (Grainger, Dodson & Korff, 2017). This ratio is calculated by multiplying the crotch length (measured barefoot) by a factor of 0.883. For example, if the inseam is 90 cm, the ideal distance between the bottom bracket and saddle would be 79.47 cm (90 cm x 0.883).

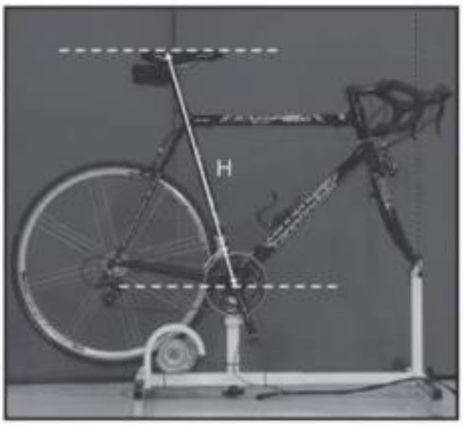

Figure 2. Distances are used for placement in the LeMond method (Bini et al., 2011)

It is important to note that this ratio may vary slightly between individuals due to anatomical differences and personal preferences. Therefore, it is recommended that fine adjustments be made to the saddle position until the most comfortable and efficient configuration is found for each rider.

- Heel method (Figure 3): This empirical method is widely used in the cycling world. It is based on the position of the cyclist's knee when the heel rests on the pedal at the lowest point of the pedalling revolution. The knee should remain fully extended at this point. This is considered an optimal position for greater efficiency and comfort during pedalling (Swart & Holliday, 2019).

Figure 3. Heel method (Bini et al., 2011)

- Holmes method (Figure 4): The knee angle when the pedal is at the bottom dead centre (180º) and the cyclist is seated in the saddle should be between 145º and 155º (Fonda, Sarabon & Li, 2014).

Figure 4. Knee flexion analysis with the crank at 180° (Holmes, Pruitt & Whalen, 1994)

- Howard method (Figure 5): Unlike the heel method, this method focuses on the cyclist's knee flexion. According to this method, when the pedal gets to its lowest point and the crank is perpendicular to the ground, the knee joint should reach approximately 30° of flexion. This position is considered more ergonomic and allows a better transmission of the cyclist's power to the pedal (Chapman et al., 2008).

Figure 5. Howard method (Bini et al., 2011)

Maintaining this ratio allows the rider to pedal with adequate leg flexion, without reaching full extension which could lead to discomfort or injury. It also promotes an optimal transfer of force from the leg muscles to the pedals, thus maximising pedalling efficiency.

Each of these methods, widely used in cycling, has advantages and disadvantages. The final saddle height adjustment, however, may require additional testing and adjustment to find the most comfortable and efficient position for the individual rider. The method chosen will depend on the individual preferences and characteristics of each cyclist, as well as the recommendations of coaches and experts in cycling biomechanics.

Besides the height, the saddle should be levelled or slightly tilted forward. To check this adjustment, the pedals should be placed in a horizontal position (at 3 o'clock and 9 o'clock): at this point, the front knee should be vertically aligned with the pedal axle. A saddle that is too far forward can cause knee strain and lower back discomfort. If it is too far back, it can cause pain in the hips and inefficient posture, as well as increase the risk of injury.

In addition to knee injuries, cycling can also cause problems in other areas such as the back, hands, and genital area, depending on the position and adjustment of the other elements of the bicycle (like handlebars, saddle, and pedals, for example) (Bini et al., 2011). Therefore, it is crucial to pay attention to the correct adaptation of the bicycle to the individual characteristics and needs of each cyclist to prevent the occurrence of injuries and ensure a safe and healthy practice of this sport (Mellion, 1991).

Handlebar height, in turn, depends on comfort and pedalling style. It should be at saddle height or slightly higher for a more upright posture. Handlebars that are too low can cause strain on the back, shoulders, and neck, which can lead to chronic pain; and handlebars that are too high, although less common, can make the cyclist feel unstable when pedalling.

With these two elements in mind (saddle and handlebar), it is also important to consider the distance between them, as the cyclist must be able to reach the handlebars comfortably without stretching too much or slouching. When sitting on the saddle with the hands on the handlebars, the arms should form a slight angle (approximately 90°). If the distance between both elements is too long, there is an increased risk of overloading the vertebrae and suffering from low back pain (LBP) as well as wrist fatigue (Wadsworth & Weinrauch, 2019). Shortening this distance does not cause such problems on the back, but if it is too short it worsens the biomechanics of pedalling and decreases power.

Finally, we must also make sure that the pedals are properly adjusted to the shoes. If cleats are used, it is necessary to check that they are correctly positioned to avoid injury due to overload or misalignment. The ideal position of the pedal spindle is midway between the first and fifth metatarsal heads (Figure 6). This allows maximum use of the force applied to the pedal and transmits power efficiently (Pruitt & Matheny, 2002).

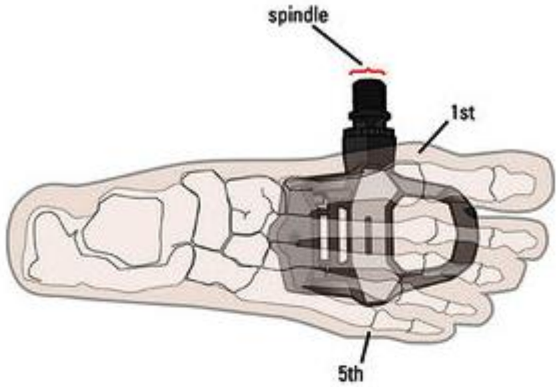

Figure 6. Correct placement of shims (Pruitt & Matheny, 2002)

Therefore, the proper fit of a bicycle is essential to adapt it to the unique needs and characteristics of each rider (Swart & Holliday, 2019) (Figure 8; Table 1).

2. PEDALLING RATE

Another of the aspects that will guarantee the correct development of the IC session is the use of an adequate pedalling technique and cadence.

Pedalling is the basic motor pattern in IC, and it is a movement that involves minimal risk of injury due to three fundamental aspects (Barranco-Gil et al., 2024). First, it is a cyclic movement, which allows a continuous and fluid execution without subjecting the joints to sudden impacts (Momeni, Faghri & Evans, 2014). Second, it does not involve significant joint impact, unlike other exercises such as running or jumping (Noriega-González et al., 2023). Third, it is a flexion-extension movement in the sagittal plane of the main joints involved, such as the hip, knee, and ankle, without reaching maximum ranges of motion at any time during the pedal cycle (Figure 7) (Galindo-Martínez et al., 2021).

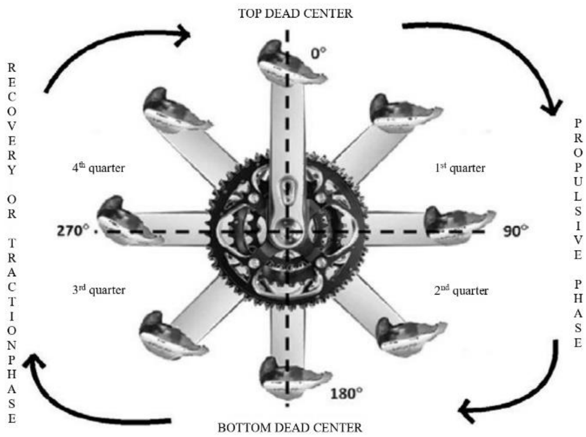

Figure 7. Separate phases and relevant points in the pedal cycle (Bini & Carpets, 2014)

Since cadence varies little between two consecutive cycles and throughout a cycle, it is assumed that the angular velocity of the crank is constant throughout a pedal cycle (Gonzalez & Hull, 1989). From the results obtained from four consecutive pedal cycles at a constant cadence of 86.2 revolutions per minute (rpm), it can be concluded that, under constant pedalling conditions, all cycles are performed at the same cadence. These results agree with the theoretical model of the kinematic behaviour of the crank already described by Burke (Burke, 1986). Therefore, under steady pedalling conditions, the average cadence of a given number of cycles is representative of what happens in each cycle.

Cadence is the changing kinematic element that has been most studied in the specific literature, as it is the only one that can change freely by altering the pedalling speed and the resistance used (Gregor, Broker & Ryan, 1991). Moreover, it is a simple measurement and control tool that has been extensively studied under unfavourable laboratory conditions (Rodríguez-Marroyo et al., 2003).

The 'optimal pedalling cadence' has undoubtedly been one of the most debated parameters because of the value placed on the lack under these conditions. In 1929 it was established that the ideal pedalling cadence was 33 rpm (Nitsch et al., 2002). This has subsequently been shown not to be the case (Belluye & Cid, 2001). In turn, they obtained the following conclusions: a) there is an ideal pedalling frequency for each power; b) the optimal pedalling frequency increases in parallel with power; c) the increase in energy expenditure (excess VO_2) when pedalling below the optimal frequency is greater for high power than for low power; d) the increase in energy expenditure when pedalling above the optimal frequency is greater for high power than for low power (Izquierdo Macón & Gómez Alonso, 2003).

These conclusions are justified from a physiological point of view and, although fascinating at the time, were mostly far from reality.

Many authors have subsequently shown that the cadences chosen range between 90 and 100 rpm, which exceeds energetically optimal considerations (Rodríguez-Marroyo et al., 2003).

How can these differences be explained? Studies on the physical and biological effects of cadence changes may show divergent opinions, although they may also be partly justified when using ergometers that do not simulate inertia or other materials (Gregor et al., 1991). In general, some explanations can be given for these divergences:

- Variability in the parameters used to define pedal power efficiency, such as VO_2, gross efficiency, etc. (Chavarren & Calbet, 1999). Several of these parameters, when combined with recordings of vastus lateralis and gluteal electrical activity, have been shown to decrease at higher cadences (Lucía et al., 2004).
- Increased subjective perceived exertion at low cadences is related to central (cardiopulmonary) and peripheral (muscular and joint) sensations (Gregor et al., 1991; Lucía et al., 2000). However, it is not clear how the subjective perceived exertion behaves with cadence manipulations: for some authors, it increases while for others it decreases (Rodríguez-Marroyo et al., 2003).
- Reduced peripheral muscle demand, which can be calculated by summing the ankle, knee, and hip joint moments over one pedal cycle (Gonzalez & Hull, 1989). From a biomechanical perspective, several studies have supported an increasingly popular theory (Belluye & Cid, 2001; Marsh et al., 2000), which advocates a certain pedalling cadence because it decreases the motor cost of pedalling. A decrease in the force applied to the pedal is indicated by an increase in cadence, which is also called "pedal speed". So far, the motor cost of the pedal should be the same at high and low cadences, a fact that does not occur as force and speed do not have a linear relationship (González Badillo & Gorostiaga Ayestarán, 1995). This suggests that the forces applied at higher cadences are proportionally lower than the increase in cadence.

Evaluation of the force applied to the pedals at different cadences has validated this hypothesis (Sanderson, 1991). It seems obvious that the best way to reduce peripheral muscle fatigue is to use lighter pedalling patterns, as they reduce the effort required by the various joints and, at the same time, involve greater energy expenditure (Faria, 1992). However, studies on the cadences were chosen to distinguish between those pedalling on a plain and those pedalling on the ascent of a mountain pass (Rodríguez-Marroyo et al., 2003; Lucía, Hoyos & Chicharro, 2001). These studies show that the cadence chosen in mountain passes is 70-75 rpm instead of 90-100 rpm since cyclists spend most of their time pedalling. According to the arguments in favour of seated pedalling, in this type of work where the potential of cyclists is greater, a higher cadence should also be chosen; therefore, the only possible defence is to discuss an ideal cadence for pedalling.

It has been shown (Richard Davison et al., 2000; Swain & Wilcox, 1992) that this cadence decreases with increasing resistance (gradient). Therefore, it can be argued that the optimal cadence during standing pedalling is lower than during seated pedalling due to the following reasons: a) the use of the foot reduces the distance from the joints to the point where force is applied and this tactic, together with the use of body weight, allows greater force to be applied to overcome the additional resistance of the slope; b) it is necessary to decrease the cadence as the force applied to the pedal increases to generate high levels of muscle tension (force-velocity ratio during muscle contraction). Despite this hypothesis, some studies have shown that the cyclists who perform best on mountain passes are those with the smallest pedalling cadences (Lucía, Joyos & Chicharro, 2000), a fact which leads to determining that cyclists with the greatest 'capacity' to maintain high cadences throughout a bike ride are those who can generate the necessary force on the pedals in the time allotted to each pedalling cycle.

Then, several factors can be listed that influence the 'optimal pedalling cadence' (Redfield & Hull, 1986), being these:

- The height of the rider. Taller cyclists use lower cadences for the same amount of power, which is justified by the fact that the cost of their pedal motor is ideal for a lower pedalling cadence (Belluye & Cid, 2001; Gonzalez & Hull, 1989).
- Level of practice. The higher the level of practice, the higher the pedalling cadences for any type of work performed at the same speed (same power), since their 'capacity' to impose the necessary force on the pedal is greater (Gregor et al., 1991; Alvarez San Martin, 1996; Rodríguez-Marroyo et al., 2003; Padilla et al., 1999).
- Pedalling cadence (Álvarez San Martín, 1996; Rodríguez-Marroyo et al., 2003; Lucía et al., 1999).
- Pedalling while standing or sitting. When pedalling while standing, the cadence must decrease to be able to apply the necessary force (Lucía et al., 1999).
- Bicycle geometry. Variables such as crank length and saddle height or depth will influence the motor cost of the pedal and, consequently, the pedalling cadence (Belluye & Cid, 2001; Gonzalez & Hull, 1989).

Nowadays, the work techniques used in IC sessions are simple, as this activity has evolved towards a more simplified and oriented approach to pedalling as a fundamental motor pattern, given its effectiveness and safety compared to other complementary exercises that were previously used (such as simulated curves, jumping on the saddle, etc.). These techniques focus on taking advantage of the inherent characteristics of pedalling, as a cyclic and low-impact movement, to achieve effective and safe training (Chavarrias et al., 2019).

In this way, the following techniques can be established:

a. Flat riding:

Flat riding simulates pedalling on flat land, and smooth terrain, where the resistance is gentle and the pedalling cadence fast (never more than 110 rpm) in a seated position, avoiding bouncing on the saddle. This training technique should not be prolonged for more than three consecutive minutes, as the aim is to maintain a constant and efficient pedalling rhythm without generating a significant effort. This type of exercise helps to improve the pedalling economy and to accustom the cyclist to maintain an optimal pedalling cadence (González-Sánchez et al., 2019).

b. Climbing:

Climbs simulate climbing a slope, hill, or mountain pass. Climbing can be performed both in standing and seated positions, with high braking resistance and slow to medium pedalling cadences (between 60-90 rpm). Depending on the length, three types can be described:

• Ports: Climbing exercises of long length, between 8 and 15 minutes. They allow you to work on your endurance and capacity for sustained effort.

• Climbs: Medium-length climbs, between 3 and 8 minutes. They develop power and the ability to sustain effort at high intensity.

• Steep climbs: short climbs, between 1 and 3 minutes. Improve explosiveness and acceleration capacity.

c. Sprint:

Sprints are considered high-risk exercises, so they are only exceptionally included in the training sessions of very advanced groups, both technically and physically (Furrer, Hawley & Handschin, 2023). They are performed by pedalling while standing at a speed between 90-100 rpm, always with a high braking resistance, and with a maximum length of 30 seconds. These sprints help develop power and the ability to accelerate quickly (Bertucci, Taiar & Grappe, 2005).

Thus, in IC sessions, it is essential to set a pedalling speed limit to ensure the safety of the participants. This prevents cyclists from reaching excessively high speeds that may compromise their physical integrity (Peeters et al., 2024). The limit of 130 rpm has traditionally been considered the desirable maximum for cyclo-ergometric exercises (Paton, Hopkins & Cook, 2009). However, nowadays, most exercise and rehabilitation training schools have opted to set lower cadence limits (Whitty et al., 2016). This trend responds to the fact that excessively high pedalling speeds can compromise the correct technical execution of pedalling and, consequently, the effectiveness and safety of exercise (Korff et al., 2007).

By limiting the cadence to more moderate values, for example, between 60 and 90 rpm, the subject is allowed to maintain minimal braking resistance, which facilitates control of the movement and the adoption of a pedalling technique by established canons (Hodson-Tole, Blake & Wakeling, 2020). In this way, the cycle ergometer (CE) becomes a much safer and more appropriate tool for use in therapeutic exercise and fitness programmes (Forestieri et al., 2016).

In addition, the strategy of limiting the maximum cadence favours the activation of muscle groups in a more balanced way, avoiding punctual overloads and minimising the risk of injury (Bini et al., 2014). All this contributes to making CE training more effective and safer for participants, regardless of their level of fitness or their therapeutic or sporting goals (González-Sánchez et al., 2019).

The risks of using excessively fast cadences during cycling seem to be obvious. Several studies have investigated this issue and found some worrying evidence. For example, reviews of the most common cycling injuries (Dettori & Norvell, 2006) link the use of high cadences to inflammation of the iliotibial band, which is an important structure for the stability of the knee. For this reason, some experts recommend setting limits on pedalling speed. Thus, several studies (Bini et al., 2010; González-Sánchez et al., 2019) suggest that the maximum cadence should be 110 rpm, provided that proper pedalling technique is maintained, and appropriate braking resistance is used. These limits are based on several previous studies that have analysed the typical cadences of cyclists.

For example, it has been observed (Caria et al., 2007) that the average cadence during the sessions analysed was 83 ± 8 rpm for men and 77 ± 13 rpm for women, without exceeding 120 rpm at any time. On the other hand, it has already been observed that the ideal maximum target cadence is around 110 rpm during the sessions (Piacentini et al., 2009), recording a maximum average cadence of 101.5 ± 4.0 rpm in a two-minute seated pedalling section, although other authors (López-Miñarro & Muyor Rodríguez, 2010) lower this maximum target cadence to 100 rpm in their research protocol.

These findings suggest that, while cyclists can sometimes reach remarkably high cadences, experts recommend maintaining more moderate levels, around 100-110 rpm, to avoid potential injuries and to preserve proper pedalling technique (Leirdal & Ettema, 2011). It is important to strike a balance between efficient cadence and the prevention of musculoskeletal problems.

In this regard, a target cadence for a training protocol of 102 revolutions per minute (rpm) maximum was established (Bianco et al., 2010). This cadence was carefully selected by the researchers, as it has been shown that maintaining an optimal pedalling cadence can improve mechanical efficiency, reduce muscle fatigue, and optimise performance during physical activity (Mater, Clos & Lepers, 2021).

The choice of a cadence of 102 rpm was based on previous scientific evidence suggesting that this pedalling frequency is within the range considered to be the most efficient for most cyclists (Mater et al., 2021). Maintaining this target cadence during training can help participants develop a more economical and fluid pedalling pattern, resulting in better energy utilisation and a reduced sense of exertion (Stebbins, Moore & Casazza, 2014).

In addition, the training protocol included specific strategies and exercises so that subjects could familiarise themselves with this target cadence and maintain it consistently throughout the training sessions (Soni, Wijeratne & Ackland, 2021). In this way, the researchers sought to optimise the physiological and biomechanical benefits associated with an efficient pedalling cadence (Table 1).

3. INTENSITY CONTROL

Multiple studies consider that the training intensity during IC sessions is very high, which can have serious consequences for the health of people with low cardiovascular fitness, sedentary or older people who start an IC programme (Battista et al., 2008; Caria et al., 2007; Piacentini et al., 2009). These studies warn that IC may be too demanding and dangerous for individuals not used to intense physical activity, as IC involves sudden changes of pace, high-intensity exercise, and very demanding cardiovascular efforts.

However, other authors (Bianco et al., 2010) have found significant cardiovascular improvements in a group of sedentary overweight women who practised IC for 12 weeks. Thus, it has been shown (Bianco et al., 2010) that IC is not an intense activity per se, but that the intensity can be dosed appropriately depending on the subject's goals; this should be the role of the instructor. These results suggest that IC can be beneficial for sedentary or overweight individuals, if the exercise intensity is adjusted and progressive, and the programme is supervised by a trained professional.

It is important to bear in mind that IC is a training modality that requires good prior physical preparation and gradual adaptation, especially in the case of older people or those with health problems. It is therefore essential that IC programmes are designed and guided by qualified instructors who can assess the physical condition of the participants and adapt the intensity and exercises according to their abilities and needs. In this way, IC can offer cardiovascular and fitness-enhancing benefits without compromising the health of the participants.

The practice of IC is characterised by high intensity and physical demand. According to expert recommendations (Garber et al., 2011), vigorous physical activity, such as IC, should be performed for at least 20 minutes and at least three days a week to obtain significant health benefits. It should be borne in mind that the intensity of IC is considered vigorous, which implies that elevated levels of exertion and cardiovascular demand are reached during practice.

In this way, the monitoring and control of heart rate and the perceived exertion during physical activity are key aspects of sports training. Some different resources and tools allow these parameters to be monitored and recorded together (Table 2). Furthermore, the use of these resources makes it possible to obtain an individual profile of the athlete, identifying their specific physiological responses and adaptations to different efforts. This helps to personalise and optimise training programmes, maximising results and avoiding overload or injury (Barbado Villalba, 2011).

Correlation tables between heart rate and subjective perceived exertion (Borg Scale) are one of the most widely used tools by coaches and athletes (Fisher, Fuller & Chandler, 2022). These tables integrate both indicators into a single reference, easing the control and dosage of the training load. In this way, the athlete and the coach can objectively and subjectively assess the level of demand of a session or exercise, adjusting the intensity more precisely.

Therefore, we can conclude that the correlation tables between heart rate and perceived exertion are a valuable and practical tool for the control and monitoring of training, favouring more effective and safer planning.

Conclusions

The most common injuries in IC training occur in the knee joint. This is due to the repetitive strain and load on this joint during high-intensity training. Therefore, it is crucial to pay special attention to proper positioning and adjustment of the bike to minimise the risk of injury.

The most important adjustment for optimal positioning is the saddle height. This should be adjusted so that the leg is slightly bent when completing the pedal stroke, thus avoiding full extension which could lead to knee overload. The inclination of the saddle and the distance to the handlebars also play a significant role in the correct biomechanical alignment of the cyclist.

In addition to the adjustment of the bicycle, it is essential to establish and respect a pedalling speed limit. It can be said that the 'optimal pedalling cadences' differ when studied from a biomechanical or an energetic point of view. It is recommended to maintain a pedalling rate between 60 and 90 rpm to avoid premature muscle fatigue and to reduce the impact on the joints.

Before the regular practice of IC, a period of progressive physical adaptation is recommended. This will allow the body to gradually become accustomed to the cardiovascular and muscular demands involved in this type of training, thus reducing the risk of injury.

Finally, control and monitoring systems, such as the use of a heart rate monitor, should be used. This will help to keep exercise intensity within heart-healthy ranges, avoiding exceeding the recommended limits for everyone.

4. *PRACTICAL APPLICATIONS*

IC offers a wide range of practical applications that go beyond simple physical exercise. Its versatility makes it a valuable tool for those looking to lose weight, improve athletic performance or simply enjoy a fun and motivating physical activity.

On a practical level, we can highlight that IC is an excellent way to increase cardiovascular endurance, which can improve heart health and lung capacity. The sessions can be highly effective in burning calories, which helps with weight loss or weight maintenance. Although it focuses primarily on cardiovascular training, it also strengthens the leg muscles (quads, hamstrings, glutes) and core. Sessions often incorporate high-intensity intervals followed by recovery periods, which can be highly effective in improving overall fitness and increasing metabolism. It is a low-impact activity that may be suitable for people in rehabilitation or those with joint injuries, allowing for a safe workout without putting too much strain on the joints. In addition, it can be used as part of an active recovery programme to help athletes recover after intense workouts.

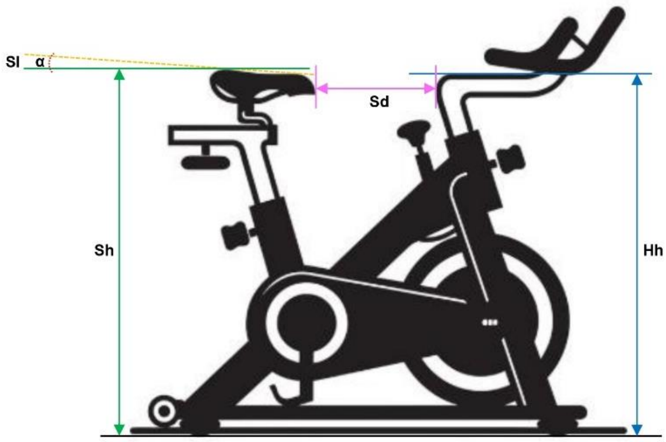

Figure 8. Measurements are to be considered when fitting the bicycle (Table 1)

Table 1. Summary of bicycle settings and cadence

SADDLE				HANDLEBAR (Hh)	SPEED				
Height (Sh)		Height (Sd)	Level (Sl)		Flat	Climbing			Sprint (standing)
						Steep climbs	Climbs	Ports	
						60-90 rpm			
cM	Inseam length (cm b) x 1.09	Sitting, hands on handlebars, arms should form approx. 90°	It should be level or slightly tilted forward.	Same saddle height or a bit higher	<3´ <110 rpm (optimal 102 rpm)	1´-3´	3´-8´	8´-15´	90-100 rpm <30´´
GtM	Ground to greater trochanter distance								
itM	Ischial tuberosity height (cm b) x 1.13								
LM	Crotch length (cm b) x 0.883								
hM	Knee fully extended								
HM	Knee at 30º								

cM: crotch method; GtM: greater trochanter method; itM: ischial tuberosity method; LM: Lemond method; hM: heel method; HM: Howard method; b: barefoot. Sh: Saddle height; Sd: Saddle Depth; Sl: Saddle level; Hh: Handlebar height.

Table 2. Intensity parameters to consider

	INTENSITY CONTROL						Weekly accumulation
	VO_{2R} (%)	VO_{2max} (%)	$_{max\text{-}resv}$HR (%)	$_{max}$HR (%)	Perceived Exertion	Metabolic equivalence	
Vigorous	70 - 85%	64 - 90%	70 - 85%	77 - 95%	14-17	MET: 6 - 8.7	≥ 75 m/w 3 - 5 d/w

VO2R: oxygen reserve consumption; max-resvHR: maximum heart rate reserve; maxHR: maximum heart rate; m: minute; w: week; d: day.

Future lines of research

As future lines of research, we believe that it is necessary to establish saddle positioning criteria according to gender due to the differences that exist in terms of hip anatomy, as women tend to have a wider pelvis and a shorter distance between the femoral trochanters, which leads to a more open position of the legs when pedalling. In addition, the pelvic tilt of the female pelvis tends to be greater, which influences the optimal saddle position. Ignoring these gender factors can lead to discomfort, inefficiency and even injury during cycling.

On the other hand, it would be necessary to determine which methodology is more effective for IC training clearly: one based on functional power threshold, or one based on anaerobic ventilatory threshold, as both approaches have their advantages and challenges.

Author contributions

Conception, ÁM-O; methodology, ÁM-O and M-AR-R; software, ÁM-O; formal analysis of the data, ÁM-O and M-AR-R; investigation, ÁM-O; writing—original draft preparation, ÁM-O and M-AR-R; writing—review and editing, ÁM-O, M-AR-R and JC-G; visualisation, ÁM-O and JC-G; supervision, JC-G; project administration, ÁM-O. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

All authors certify that they have no affiliation or involvement with any organisation or entity with financial or non-financial interest in the subject matter or materials covered in this manuscript.

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