RELATIONSHIP BETWEEN STRENGTH AND POWER PRODUCTION CAPACITIES IN TRAINED SPRINT TRACK CYCLISTS

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Original scientific paper
UDC: 796.61:796.012.11

Abstract:

The purpose of this study was to investigate the relationship between strength and power capabilities in trained sprint track cyclists. Ten participants including six women and four men (age: 22.1±6.8 years, body height: 176.1±6.7 cm, body weight: 72.1±7.9 kg) performed isometric mid-thigh pull (IMTP) and isokinetic sprint tests. Variables measured included peak force (PF), peak rate of force development (PRFD) for the IMTP and maximal torque and maximal power (Pmax) for the isokinetic sprint test. There was a strong relationship between PF on the IMTP and maximal peak torque values across five isokinetic sprints (r=.890-.925). Strong relationships were also shown between PRFD on the IMTP and maximal torque during isokinetic sprints (r=.696-.755). No significant relationships were found between PF and Pmax produced during isokinetic sprints. The findings suggest that isometric testing can provide useful insights into force capabilities of sprint track cyclists. Strength and conditioning practitioners should improve strength and explosive force capabilities of their athletes if the desired outcome is to increase torque application and power production during maximal sprint cycling.

Key words: *cycling, resistance training, force*

Introduction

The sport of track cycling is seen as a sprint based cycling discipline with athletes required to perform either a maximal single bout sprint or repeated sprint bouts during events ranging from 250 m to 30 km in length (Craig & Norton, 2001; Martin, Davidson, & Pardyjak, 2007). In order for athletes to be successful in these events power production must be optimised (Dorel, et al., 2005; Gardner, et al., 2005, 2007; Martin, et al., 1997; 2007). However, tactical and psychological factors may also influence performance regardless of power production optimisation (Menaspa, Abbiss, & Martin, 2013; Schumacher, et al., 2001). In relation to cycling, power can be defined as the product of torque applied to the pedal surface by the working musculature in relation to the velocity of the rotating crank arm (Emanuele & Denoth, 2011; Martin, et al., 2007; McCartney, et al., 1985; Samozino, et al., 2007). The interaction between torque application and crank velocity is commonly measured through the force-velocity relationship, with peak power reported to occur when force application to the pedal surface and crank arm velocity are optimised (Emanuele & Denoth, 2011; Fonda & Sarabon, 2010; Martin, et al., 2007; Martin, Lamb, & Brown, 2002; Samozino, et al., 2007).

During a maximal sprint bout peak power has been reported to occur between 120-140 revolutions per minute (rpm), also known as the optimal pedaling rate of power (Dorel, et al., 2005). Literature on optimal pedaling rate has shown that a crank velocity of 120-140 rpm is significant in allowing maximal contractile force and contractile velocity of the recruited muscle fibres, while crank velocities higher than 140 rpm have been shown to negatively impact the ability for forceful contractions of the recruited muscle fibres (Dorel, et al., 2005; Gardner, et al., 2007; Martin, et al., 2007; Martin & Brown, 2009). Sports where power demands are a significant contributing factor to performance have shown that increases in muscular strength are advantageous in improving overall power production capability (Cormie, McGuigan, & Newton, 2011; Izquierdo, et al., 2004; Saez de Villarreal, et al., 2013). The measurement of muscular force through isometric contraction is one such way in which force production capability can be established for power oriented athletes (Stone, et al., 2004). Although the use of isometric strength measures has been criticized due to its lack of specificity in characterizing dynamic power exercises (Stone, et al., 2004). However, a study by Stone et al. (2004) found a strong correlation between isometric strength and cycling success, indicating that an isometric assessment for sprint oriented athletes can be informative.

There is a lack of understanding regarding the relationship isokinetic force production has with maximal power output during short bouts of sprint cycling. Rannama et al. (2012) using an isokinetic dynamometer showed that high levels of isokinetic force produced from the hip, knee and ankle joint had a significant impact on the ability to produce high levels of power during maximal cycling bouts. To better understand the relationship between muscular force and cycling, power production attempts should be made to measure isokinetic force of the lower limb joints during a cycling specific movement. Further understanding of the force velocity relationship and optimal pedaling rate phenomenon using trained cyclists would be beneficial to practitioners to aid in gear ratio selection and overall training prescription. Therefore, the purpose of this study was to investigate the relationship between the strength and power capabilities in highly trained sprint cyclists. In addition, the study investigated the impact maximal force production had on optimal pedaling rate characteristics.

Methods

Subjects

Ten trained track cyclists (6 women and 4 men, age: 22.1±6.8 years, body height: 176.1±6.7 cm, body weight: 72.1±7.9 kg) volunteered as participants for this research. All participants had competed in a Track Cycling National Championships in New Zealand or a higher-level competition within the past twelve months and had experience of gym based resistance training. All participants were free of injury or physical disability that would affect their ability to perform the required tests maximally. Subjects were informed of the risks and benefits of the participation in this study and signed an informed consent form prior to the participation. The Auckland University of Technology ethics committee approved the procedures for this study prior to the commencement of data collection.

Methodology

Prior to testing, all subjects completed a standardized warm-up consisting of a five-minute stationary bike warm-up (TechnoGym, New Zealand) followed by ten repetitions of body weight squat and push up from the knee or feet. Once the standardized warm-up had been completed, a demonstration was given to each subject of the correct technique and procedure for performing the IMTP assessment. This was followed by a familiarization period with the IMTP, consisting of three trials at 50%, 70% and 90% of perceived maximum exertion to ensure the correct technique and understanding of the requirements for maximal effort.

Participants then completed three maximal IMTP lasting approximately three to five seconds for each effort (Stone, et al., 2004). Before the commencement of each trial, participants were instructed to pull as hard and fast as possible. Sufficient recovery of three minutes was prescribed between trials to ensure that maximal effort could be applied during each trial. For the IMTP a force plate (Fitness Technologies, Adelaide) sampling at 600 Hz was used to collect kinetic data. The force plate was placed within a specifically built rack (Fitness Technologies, Adelaide), which allowed for a fixed barbell to be placed at a selected height. Barbell height position was determined using previously established bar height protocol by Stone et al. (2004) with participants establishing and maintaining a knee angle of 140-145 degrees and an almost near vertical trunk position throughout each trial. Both peak force (PF) and peak rate of force development (PRFD) were recorded for each trial, with the two highest values of the three trials were then averaged out and used for data analysis. The reliability of this test is high in our laboratory with intraclass coefficient correlations (ICC) values for PF of >.98, and coefficient of variation (CV) <3%. At the completion of the IMTP assessment study participants had twenty minutes of passive recovery before completing the next test.

The second assessment was carried out using a Lode ergometer (Lode, Groningen). The ergometer was configured to the exact dimensions (saddle height, headset height and saddle to headset distance) for the participants own bicycle and each participant used their own shoes and pedals. A standardized warm-up of seven minutes at 70 rpm and 100 W preceded the on-bike power assessment. On completion of the warm-up participants rested for two minutes in a passive state. Participants then performed five maximal isokinetic sprints (60 rpm, 80 rpm, 100 rpm, 120 rpm and 140 rpm) of approximately eight seconds, with three minutes of active recovery (50 W) between each sprint. Each sprint was performed from a stationary standing start position, with the participants' favored foot placed in the forward position at a preferred crank angle. Subjects were instructed to remain out of the seat throughout each eight-second sprint. Torque and crank arm velocity were measured through strain gauges on the crank. Torque, Pmax and crank arm velocity were used as performance determinants in this assessment. Intra-class correlation coefficients of 0.96-0.98 have been reported for maximal power output and velocity measurements during isokinetic cycle sprints (Koninckx, Van Leemputte, & Hespel, 2010), suggesting that the use of isokinetic sprint profile test was suitable for this research.

Statistical analysis

Data were reported as mean ± standard deviation with statistical significance set at $p \leq .05$. Pearson product moment correlation was used to explore the relationships between variables. Correlations of <.3, <.5, <.7, <.9, <1.0 were considered small, moderate, large, very large and nearly perfect, respectively (Hopkins, et al, 2009).

Results

Means and standard deviations for PF, PRFD and Pmax values for all isokinetic inertial ergometer sprints are shown in Table 1. No significant correlations were found between PF or PRFD and Pmax for each prescribed pedaling rate.

Pmax was shown to be a parabolic function of crank velocity with maximal power increasing in relation to crank velocity during the 60 rpm and 80 rpm isokinetic sprints before reaching a maximum at 100 rpm and decreasing at a similar rate during 120 and 140 rpm isokinetic sprints. Maximal power ranged from 843 W to 1692 W, with all peak power values occurring during the 100 rpm isokinetic sprint.

All subjects showed an inverse relationship between peak torque and pedal crank velocity. The highest peak torque values were found during the 60 rpm isokinetic sprint and ranged from 167 N to 261 N (Table 2 and Figure 1). The group maximal torque values for each inertial ergometer sprint are outlined in Table 2. The significant correlations were found between PF and maximal torque values for all five isokinetic sprints (Table 3). The correlations between PRFD and maximal torque are also shown in Table 3.

Table 3. Correlations of maximal strength values with maximal torque and power values

	Peak force	**PRFD**
Torque 60 rpm	0.907*	0.733
Torque 80 rpm	0.925*	0.751
Torque 100 rpm	0.889*	0.696
Torque 120 rpm	0.892*	0.741
Torque 140 rpm	0.890*	0.755
Power 60 rpm	0.533	0.588
Power 80 rpm	0.117	0.275
Power 100rpm	0.198	0.385
Power 120 rpm	0.167	0.381
Power 140 rpm	0.207	0.485

Note. * = Significant correlation (p≤0.05), PRFD = peak rate of force development

Table 1. Maximal values for isometric mid thigh pull assessment and inertial ergometer sprint test

	Isometric mid thigh pull (N)		**Inertial ergometer sprint test (W)**				
	PF	PRFD	60 rpm	80 rpm	100 rpm	120 rpm	140 rpm
All							
Mean	2139	11318	1137	1187	1294	1222	1145
SD	710	8083	68	259	332	345	344
Male							
Mean	2212	12387	1157	1457	1603	1541	1432
SD	1009	7226	2	81	77	66	150
Female							
Mean	2091	10677	1125	1044	1109	1033	978
SD	655	8592	88	207	274	294	319

Note. PF = isometric peak force; PRFD = peak rate of force development

Table 2. Maximal torque values for isokinetic sprint test

	60 rpm	**80 rpm**	**100 rpm**	**120 rpm**	**140 rpm**
Mean	189.9	181.6	159.5	134.0	116.9
SD	48.3	45.9	41.2	33.3	31.7

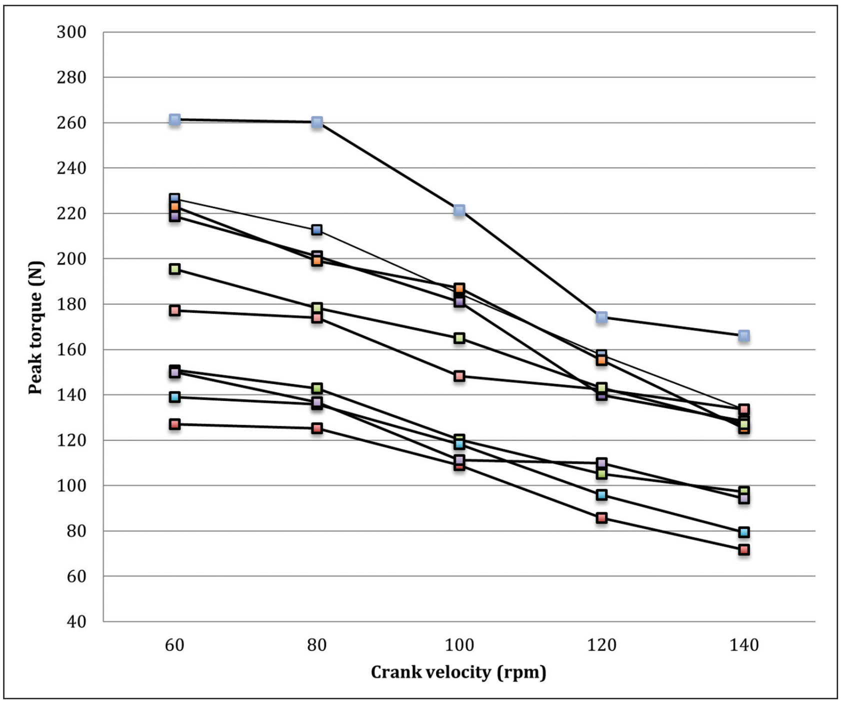

Figure 1. Individual maximal torque and crank velocity relationships.

Discussion

Overall the findings of the study show that isometric assessment can provide useful insights into force capabilities of sprint track cyclists. The strongest correlations were found between PF and maximal torque values produced during the 60 rpm and 80 rpm isokinetic sprint (r=.907 and .925). The highest torque values (189 N) were also found during the 60 rpm isokinetic sprint. The high maximal torque values produced during the 60 rpm isokinetic sprint can be suggested to be a result of the increased maximal strength required to overcome a high relative load applied to the ergometer fly wheel, compared to the higher velocity isokinetic sprints which would have a smaller relative load to overcome. Correlations between PF and maximal torque application were also found during the high-velocity isokinetic sprints of 100, 120 and 140 rpm (r=.889, .892 and .890, respectively), although maximal torque values were less than that seen during the low velocity isokinetic sprints. This indicates that while there is still a significant requirement for muscular strength to produce torque to the rotating crank arm, the level of effort or requirement of muscular strength is far less than that required during the low velocity sprints. Previous literature on the effect that inertial loading has on torque application has shown that maximal torque is reduced as a result of a decreasing moment of inertia caused by an increase in crank velocity (Hansen, Jorgensen, Jensen, Fregly, & Sjogaard, 2002). The correlations found between PF and maximal torque during sprint cycling within the present study provide better understanding of the ability to apply muscular force to produce high levels of power during maximal sprint cycling. Similar to Stone et al. (2004), the correlations found between PF and maximal torque appear to suggest that if an athlete is able to increase muscular strength, this will result in an increased torque production across a range of different pedaling velocities. Very few studies have examined this relationship within trained sprint cyclists (Kordi, et al., 2017; Stone, et al., 2004). Kordi et al. (2017) showed that knee extensor peak torque was the best predictor of peak power output in track sprint cyclists. A study by Stone and colleagues (2004) found maximum strength to be strongly related with both coaches ranking and sprint cycling performance. The relationship between maximal torque production capability and crank velocity identified within the current study further supporting findings regarding the force-velocity relationship in trained and untrained cyclists. In particular the established relationship between a reduction in maximal torque when crank velocity is increased is consistent with findings previously found in the lab and field settings (Emanuele & Denoth, 2011; Martin, et al., 2007; McCartney, et al., 1985; Samozino, et al., 2007).

Large correlations were found between PRFD during isometric strength assessment and torque values produced during the five isokinetic sprints. This is consistent with findings of Stone et al. (2004) and indicates that the rate in which force can be applied significantly impacts maximal torque values, and consequently maximal power output. Smaller correlations found between PRFD and power may be the result of inability of the current subject pool to produce repeated maximal forces throughout the duration of each isokinetic sprint. The inability to produce repeated maximal force might be in part due to a less relative load (pedal resistance) caused by an increase in crank velocity during the latter part of each isokinetic sprint. Stone et al. (2004) noted that stronger athletes with a greater PF and PRFD may be able to produce higher repeated maximal forces at higher crank velocities resulting in the increased power production. Further research is required with larger numbers of highly trained athletes. Caution should be taken when applying the PRFD findings, as previous studies have shown poor reliability for these measures (ICC<.80)

(James, Roberts, Haff, Kelly, & Beckman, 2017; Stone, et al., 2004).

Interestingly, the findings of the present study revealed no significant correlations between Pmax achieved during the isokinetic sprints and PF. This is in contrast to Stone et al. (2004) who reported a significant relationship between PF and peak power. All participants in the study achieved maximal power during the 100 rpm isokinetic sprint, a crank velocity that falls below the range established for the optimal pedaling rate of power (110-130 rpm) (Gardner, et al., 2007; Martin, et al., 2007). Power profiles of all study participants followed a parabolic curve of power indicating that, whilst maximal power was achieved outside of the established optimal pedaling rate, the values produced during the 100 rpm isokinetic sprint were a true indicator of maximal power. The low maximal power output and optimal pedaling rate found in this study compared to other cycling specific studies (Martin, Wagner, & Coyle, 1997; Sargeant, Hoinville, & Young, 1981; Samozino, et al., 2007) could be the result of the variance in overall training experience, with the subject population of this study having on average 1.8±1.1 years of structured cycling specific training. Studies have shown that a lack of high velocity training or velocity specific training can significantly impact the ability of the working musculature to produce force at high contractile rates (Cormie, McGuigan, & Newton, 2011). This suggests that a possible lack of training or lack of experience in the area of high velocity training within the current subject pool due to the limited time carrying out structured training may have resulted in a lack of power application during the high velocity isokinetic sprints. This could go some way to explaining low relationships between peak power and force in this group.

Practical applications

The results support the notion that muscular strength directly influences torque application at any pedaling velocity during maximal sprint cycling bouts. This is an important finding as previous cycling specific literature has suggested that in order for cycling power production to be improved, either torque or velocity capabilities must be improved. The current study suggests that if muscular strength were to be improved in track cyclists, this could increase maximal torque application at a range of different pedaling rates.

While the present study has shown a significant relationship between muscular strength and torque production capabilities in maximal sprint cycling, the findings also indicate that an increase in torque alone may not be sufficient to improve maximal power levels. The use of high velocity training to improve contractile rates would most likely improve power production during higher velocity sprint cycling resulting in maximal power being achieved within the optimal pedaling rate of power. It is suggested that when designing training sessions for the purposes of improving sprint performance in a track oriented cyclist, practitioners would do best to prescribe sessions in which maximal force or maximal acceleration is required. The use of specific velocity training at velocities desired during performance could also be advantageous in improving power capabilities at a given pedaling rate.

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