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THESE

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Vice-Directeur de l'Ecole doctorale

Mesure du rendement et de la force isocinétique du genou chez une population de cyclistes coursiers et de sportifs expérimentés non cyclistes.

Paul GILLIÉRON, Cyril BESSON, Mathieu SAUBADE, Jérôme PASQUIER, Vincent GREMEAUX, Gérald GREMION

CONTEXTE : Le rendement brut en cyclisme (GE) semble corrélé à la force des membres inférieurs. Cette étude a examiné le rendement brut à quatre cadences de pédalage différentes et sa relation avec un test de force isocinétique chez des cyclistes coursiers (BM) et des sportifs expérimentés non cyclistes (NBM).

MÉTHODES : Huit BM et huit NBM ont effectué un test incrémental maximal pour déterminer la puissance aérobie maximale (MAP) et la consommation maximale d'oxygène (V̇O2max). La GE, la V̇O2, la fréquence cardiaque (FC) et la concentration de lactate sanguin (CLS) ont été mesurées à différentes cadences (60, 70, 90 et 100 rpm) pendant un test d'efficacité à 50% de la MAP et les participants ont ensuite effectué un test isocinétique du genou droit.

RÉSULTATS : Une différence a été trouvée en faveur des BM pour GE (sauf à 90 rpm), BLC et MAP/kg. La cadence la plus efficiente était de 60 rpm dans les deux groupes. L'augmentation de la cadence a entraîné une diminution du GE et une augmentation de la FC et de la V̇O2 dans les deux groupes. Le BLC n'a augmenté que dans le groupe NBM. Nous n'avons trouvé aucune relation entre le GE à différentes cadences, le couple de force maximal par rapport au poids corporel et la fatigabilité musculaire.

CONCLUSIONS : Cette étude est la première à étudier la performance et le rendement chez les BM. A puissance équivalente, les BM montrent un meilleur GE que les NBM. Ces résultats sont en accord avec les analyses décrites précédemment chez les cyclistes et s'expliquent par une meilleure capacité aérobique et un meilleur entraînement. La force maximale isocinétique du genou et la fatigabilité ne sont pas liées au GE, et ne semblent donc pas appropriées pour évaluer le GE en cyclisme.

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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Measure of efficiency and knee isokinetic strength in bike messengers and non-cyclist athletes

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ABSTRACT

BACKGROUND: Gross efficiency in cycling (GE) seems correlated with lower-body strength. This study investigated GE at four different pedaling rates and its relationship with an isokinetic strength test in bike messengers (BM) and experienced athletes non-bike messengers (NBM).
METHODS: Eight BM and eight NBM completed a maximal incremental test to determine maximal aerobic power (MAP) and maximal oxygen consumption ($\dot{V}O_{2max}$). GE, $\dot{V}O_2$, heart rate (HR) and blood lactate concentration (BLC) were measured at different cadences (60, 70, 90 and 100 rpm) during an efficiency test at 50% of MAP and participants then performed an isokinetic test of the right knee.
RESULTS: A difference in GE (except at 90 rpm), BLC and MAP/kg was found in favor of BM. The most efficient cadence was 60 rpm in both groups. Increased cadence resulted in decreased GE and increased HR and $\dot{V}O_2$ in both groups. BLC only increased in the NBM. We found no relationships between GE at different cadence, peak torque relative to bodyweight and muscle fatigability.
CONCLUSIONS: This study is the first investigating performance and efficiency among BM. At equivalent power output, BM show a better GE than NBM. Those results are in line with previously described analysis in cyclists and explained by better aerobic capacity and training status. Isokinetic knee maximal strength and fatigability were not linked with GE, and thus does not appear appropriate for evaluating GE in cycling.

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KEY WORDS: Substrate cycling; Bicycling; Muscle strength.

Bike messengers (BM) are cyclists professionally working for delivery companies and meet growing popularity as fast mean in crowded cities. This job demands a high level of fitness[1] and some of these BM have a history in competitive road cycling, mountain biking or cyclocross, while others develop their fitness through labor. Most of BM fitness is built by going around the city to earn a living. The on/off efforts required by this job are completely different from the steadier exercise experienced by competitive athletes during their training or races. These subjects are particularly interesting as they usually do not follow any special training regimen and almost no literature about BM performance capacity is available. When looking at key performance indexes in cyclists, cycling efficiency is related to performance.[2-6] Different studies on cycling efficiency were conducted on populations composed of competitive or ex-competitive road-cyclists, or non-cyclists and as far as we know, no studies on cycling efficiency were done on BM.

Cycling efficiency can be calculated in various manners.[3] Among them, gross efficiency (GE) is defined as the ratio of work accomplished per second of a machine, to the energy expended per second by a subject to activate that machine, expressed as a percentage calculated as below (W: watts; J: joule; s: second):[3, 6]

$$GE\ (\%)=(\text{Work rate [W]}/\text{Energy expended [J}\cdot\text{s}^{-1}])\times 100$$

Maximal efficiency for any sport cannot be greater than

30% since metabolic and muscular efficiency are not overtaken.[7] Cycling is the most efficient form of locomotion and cycling GE can reach up to 20-23%.[7, 8] GE is easy to measure and provides an accurate expression of efficiency in cycling. GE takes into account metabolic, muscular and mechanical efficiency. It also includes the influence of basal metabolism, digestion, muscle activation, body stabilization, etc. Influence of basal metabolic rate also decreases at higher intensity.[3, 9]

One of the many determinants of GE is pedaling rate.[9] Power output in cycling is the expression of velocity (pedaling rate) and strength development in the pedaling movement. Since exercise intensity directly influences GE[9] and is a combination of strength and velocity qualities, it is expected that strength may influence GE. Studies have shown that maximal strength training improves efficiency and performance of elite cyclists,[10-13] but also of previously untrained subjects.[14] One of the gold standards in strength testing is isokinetic test[15] and relationships between efficiency and isokinetic strength have been poorly investigated. Louis *et al*. used an isokinetic strength test with moderate speed and found no relationship between cycling efficiency and isokinetic indexes.[12] However, they found a relationship between isometric maximal voluntary contraction and efficiency. As maximal strength appears to be linked with efficiency, investigating its relationship with low speed isokinetic test would be of better interest. The previously stated studies investigated then efficiency and strength relationship with different outcomes. Maximal strength with isokinetic test was not investigated in relation with efficiency.

Purpose of this study was first to describe and compare aerobic capacity, efficiency and strength indexes of a population of BM with non-bike messengers athletes (NBM). We hypothesized that BM will not only elicit a better aerobic fitness but will also be more efficient than NBM. Then, as strength is closely related to efficiency and maximum strength training significantly improves efficiency, secondary goal is to observe if GE links with gold standard strength indexes other than those shown in different previously published studies,[10-13] thus helping to know if classic maximal strength evaluations are of interest in GE analysis.

Materials and methods

Participants

Eight male BM and eight male NBM gave written informed consent and were included in the study. BM rode 200.0 (62.5) km and were active 15.00 (14.8) per week while NBM scarcely used a bike and trained 5.50 (3.3) weekly hours. Participants had to be between 18 and 35 years old, male, in good general health, either regularly working as BM or being an experienced non-cyclist athlete training more than 3 hours a week in his sport. NBM practiced various sports (golf, ice hockey, sprint, etc.). All procedures performed in this study were in accordance with the ethical standards of the ethics committee of the Canton de Vaud, Switzerland and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Experiments

Study was designed with two laboratory sessions separated by 6.8±2.7 days. Each session took place in a sports medicine unit. All participants were requested to attend both session under similar conditions, with clipless shoes and were instructed not to ingest any food at least 1 hour prior the sessions. During the first session, each participant had a clinical check-up by an approved sports physician which included a complete clinical history, a rest EKG, a blood pressure measurement and resting heart rate in order ensure that they could safely participate in the study. Weight and height were measured and participants completed an adaptation of a maximal exercise test described in previous studies on efficiency[9, 16] using a cycle ergometer (CycleOps Pro 400, CycleOps, Madison, USA) in order to determine maximal aerobic power (MAP) and maximal oxygen consumption ($\dot{V}O_{2max}$, highest value of 20-second average). After a 6 minutes warm-up period at 100W, power was increased by 30W every minute until maximal effort was reached. During the test, oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), ventilation and heart rate (HR) were measured using a Cortex Metalyzer 3B gas exchange analyzer (Cortex Biophysik GmbH, Leipzig, Germany) and a heart rate belt (H7, Polar Electro OY, Kempele, Finland). At the beginning and at the end of the test, a sample of fingertip capillary blood was taken to measure blood lactate concentration using a Biosen C-Line analyzer (EKF Diagnostics, Cardiff, England).

During second session, an efficiency test adapted from a previously published study[9] was performed at four cadences (60-70-90-100, randomized) for a duration of 5 minutes each using a metronome to regulate participants' pedaling rate. A rest break of 2 minutes was respected between each cadence. The power output used for the test was 50% of MAP developed during the first session. $\dot{V}O_2$

and $\dot{V}CO_2$ and HR were collected and 60-second average of the last minute of each interval was kept for calculation. Fingertip blood samples were taken at the 5th minute of every interval.

After a 15-minute break, an isokinetic test (Humac Norm dynamometer [CSMi, Stoughton, USA]) was performed to determine the strength of knee extension and flexion of participants. A rigorous warm-up to prevent injury but also for familiarization was performed for each participant. Concentric strength of extension and flexion of right knee were tested with 5 repetitions at 60°/sec and 20 repetitions at 180°/sec. Right knee was chosen in the view of the absence of significant difference between right and left knee.[17] Peak torque/body weight ratio at 60°/s and fatigability at 180°/s, calculated as the percentage peak torque of the final peak torque relative to the first peak torque, were kept as outcomes.

GE calculation

Like other studies on the topic, in order to calculate the energy expenditure (W) at each cadence, Brouwer formula was used:[6, 12, 18]

$$\text{Energy expenditure (W)} = ([3.869 \cdot \dot{V}O_2] + [1.195 \cdot \dot{V}CO_2]) \cdot (4.186 \div 60) \cdot 1000$$

Statistical analysis

Since data were not normally distributed, non-parametric statistics were used. Medians and interquartile ranges were calculated for all assessments. A Spearman correlation test with bootstrap P values was used to assess intra-group relationships. Differences between the two groups were examined using an exact Wilcoxon-Mann-Whitney test. Significant difference was set at 0.05. Data were analyzed using R software 3.3.1 (The R Foundation, 2016).

Results

Intergroup differences

Age, height and weight were similar in both groups. Differences in $\dot{V}O_{2max}$ and maximal aerobic power per body weight (MAP/kg) were highlighted as shown in Table I. A significant intergroup difference was found in blood lactate concentration (BLC) at every cadence. Absolute powers for efficiency test was 205 (28.6) and 175 (23.1) W for BM and NBM, respectively. BM had a better GE at every cadence except at 90 rpm. A significant difference was found in $\dot{V}O_2$ at 60 rpm. However, when divided by their personal $\dot{V}O_{2max}$, this difference disappeared with an equivalent $\dot{V}O_2/\dot{V}O_{2max}$ ratio between groups. The greatest GE was found at the slowest pedaling rate tested and decreased as the cadence increased. Table II shows results between the two groups on GE, aerobic power, blood lactate concentration (BLC), heart rate (HR), absolute oxygen consumption ($\dot{V}O_2$) and oxygen consumption relative to participants' $\dot{V}O_{2max}$.

Table I.—*Participants' characteristics and performances.*

Parameters	BM (N.=8)	NBM (N.=8)	P value
Age (year)	25.0 (3.5)	25 (2.8)	0.878
Height (cm)	179.8 (10.5)	177.9 (1.8)	0.574
Weight (kg)	69.9 (7.9)	72.5 (3.8)	0.382
MAP/kg	5.8 (0.5)	4.8 (0.5)	<0.001
$\dot{V}O_{2max}$ (mL·min^{-1}·kg^{-1})	63.7 (4.2)	56.4 (5.0)	0.005

Results are in medians (interquartile range).
$\dot{V}O2_{max}$: Maximal oxygen uptake); MAP/kg: maximal aerobic power per bodyweight.

Table II.—*Gross efficiency test intergroup differences.*

Measurements	BM (N.=8)	NBM (N.=8)	P value
60 rpm			
Gross efficiency (%)	22.3 (0.7)	21.3 (1.0)	0.028
Heart rate (bpm)	141.0 (11.5)	142.0 (13.5)	0.959
Lactate (mmol·L^{-1})	1.6 (0.3)	3.3 (1.0)	0.002
$\dot{V}O_2$ (mL·min^{-1}·kg^{-1})	36.5 (2.0)	33.5 (2.3)	0.030
$\dot{V}O_2/\dot{V}O_{2max}$	0.59 (0.03)	0.60 (0.03)	0.505
70 rpm			
Gross efficiency (%)	21.8 (0.8)	20.9 (1.8)	0.050
Heart rate (bpm)	142.0 (10.3)	147.5 (7.8)	0.382
Lactate (mmol·L^{-1})	1.5 (0.3)	3.3 (0.5)	<0.001
$\dot{V}O_2$ (mL·min^{-1}·kg^{-1})	37.6 (3.2)	34.2 (4.8)	0.078
$\dot{V}O_2/\dot{V}O_{2max}$	0.61 (0.06)	0.62 (0.05)	0.878
90 rpm			
Gross efficiency (%)	20.5 (0.7)	19.9 (1.2)	0.105
Lactate (mmol·L^{-1})	1.5 (0.7)	3.9 (0.9)	<0.001
Heart rate (bpm)	148.0 (9.8)	151.0 (8.5)	0.574
$\dot{V}O_2$ (mL·min^{-1}·kg^{-1})	40.5 (2.9)	35.8 (3.4)	0.005
$\dot{V}O_2/\dot{V}O_{2max}$	0.64 (0.02)	0.65 (0.01)	0.442
100 rpm			
Gross efficiency (%)	20.2 (1.2)	18.9 (0.5)	0.001
Lactate (mmol·L^{-1})	1.7 (1.0)	4.5 (0.7)	0.002
Heart rate (bpm)	147.5 (11.5)	156 (10)	0.382
$\dot{V}O_2$ (mL·min^{-1}·kg^{-1})	40.2 (2.5)	36.7 (4.9)	0.101
$\dot{V}O_2/\dot{V}O_{2max}$	0.64 (0.05)	0.68 (0.05)	0.442

Intergroup differences at every cadence during efficiency test. Results are in medians (interquartile range).
$\dot{V}O_2$: Oxygen uptake; $\dot{V}O_{2max}$: maximal oxygen uptake.

Correlations and intragroup correlations

When taking every participant together, GE is correlated with MAP/kg at each cadence except 70 (correlation coefficient [r] 0.65, 0.49 (P=0.053), 0.62, 0.73 for 60, 70, 90

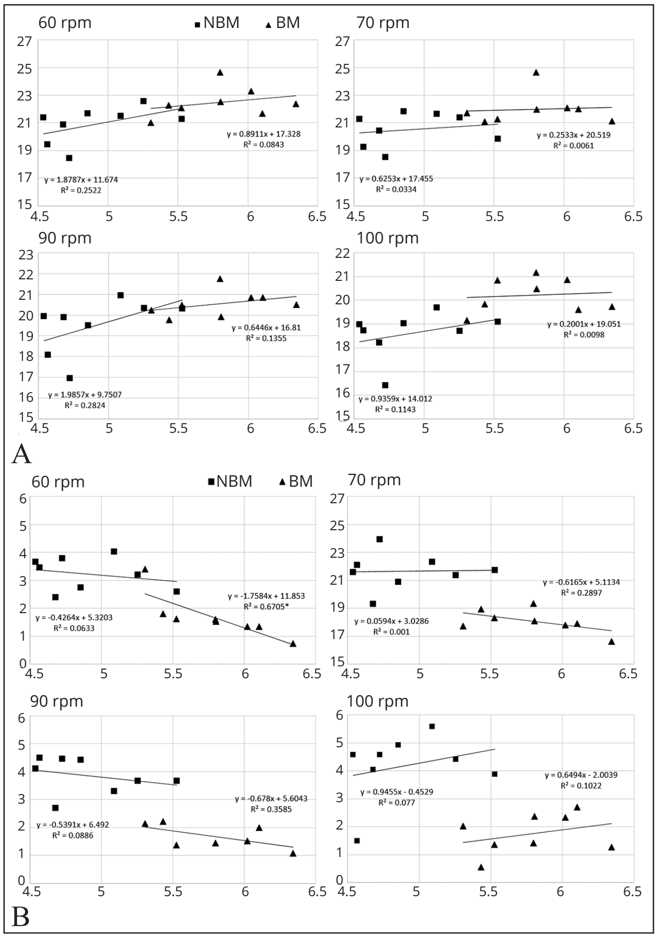

Figure 1.—A) Correlations between GE at different cadences and MAP/kg for each group; B) correlations between BLC at different cadences and MAP/kg for each group.
GE: Gross efficiency; BLC: blood lactate concentration at 50% of MAP; MAP/kg: maximal aerobic power per body weight.
*P value<0.05

and 100 rpm, respectively). $\dot{V}O_{2max}$ was correlated with GE at 90 and 100 rpm. Despite significant differences between groups, correlations coefficient are much lower when analyzing both group separately. Figure 1 presents correlations found in both groups between MAP per kilogram and GE at 60, 70, 90 and 100 rpm (Figure 1A) and between MAP per kilogram and low blood lactate at all pedaling rates (Figure 1B).

Isokinetic strength test

NBM had significantly stronger knee flexors (P value=0.036). No other significant intergroup differences were found during the isokinetic strength test as seen in Table III.

TABLE III.—*Isokinetic test intergroup differences.*

PT/bw (%)	BM (N.=8)	NBM (N.=8)	P value
Right extensors	278.5 (51.8)	302.5 (16.5)	0.396
Right flexors	149.0 (14.3)	165.5 (15.8)	0.036
Endurance			
Right extensors	90.5 (7.0)	87.5 (6.5)	0.314
Right flexors	82.5 (5.8)	78 (9.8)	0.245

Intergroup differences in peak torque at 60°/s per body weight calculated as a percentage of body weight and intergroup difference in endurance of right knee flexors and extensors (180°/S); results are in medians (interquartile range).
PT/bw: Peak torque/body weight.

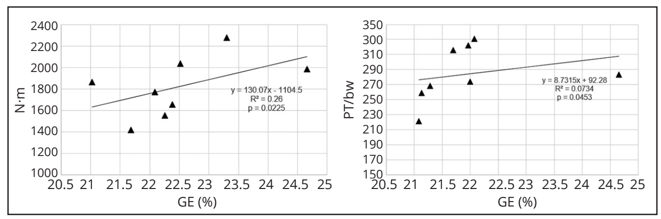

Figure 2.—Correlations between GE at 60 rpm and total work done by knee flexors at 180°/s and between GE at 70 rpm and quadriceps peak torque to body-weight ratio at 60°/s.
GE: Gross efficiency; N·m: Newton metre; PT/bw: peak torque/body weight.

Few relationships between GE and isokinetic test were found in BM. GE at 60 rpm is correlated with total work done by right knee flexors at 180°/s in BM (P value: 0.023). GE at 70 rpm is correlated with peak torque to body-weight ratio of the right quadriceps at 60°/s in BM (P value: 0.045) as presented in Figure 2. No correlations between GE and isokinetic strength test indexes were found in NBM.

Discussion

The purpose of this study was to describe and compare performance capacity, GE and knee flexion/extension strength in BM and non-cyclist athletes (NBM) and to observe potential correlation between aerobic capacity indexes, strength indexes, and GE. Results showed a significant difference in $\dot{V}O_{2max}$, MAP/kg and GE at almost all pedaling rates between groups. We only found one study considering the characteristics of a BM population.[1] They maximally tested 5 participants and found very similar aerobic capacity (63±3 mL·min^{-1}·kg^{-1}) for the same age (25±4 y). Aerobic capacity was very close to junior and U23 elite cyclists (65.5±3.9 67±7.5) but still far from professional 75.3±4.[19] This however proves the high fitness of this population, as average healthy population of this age is between.

The results or our study showed that the most efficient cadence is 60 rpm in both groups, and that altogether GE linearly decreases as pedaling rate increases. We also found that heart rate and $\dot{V}O_2$ increase in parallel with increasing cadence. Efficiency can be affected by many factors in cycling:[20] cadence;[9] body mass;[21] cycling position;[22, 23] pedaling technique;[24] prior exercise;[25] muscle fiber type;[5, 26] training status; and maximal strength training.[10-12, 14] Some of these factors are similar in both of groups, but others, such as training status and hours per week in pedaling actions may potentially explain the differences evidenced in GE. It is confirmed with the fact that NBM blood lactate concentration tends to increase with pedaling rate, whereas it stays stable in BM. In contrast to our study, previous works showed no difference in GE between trained and non-trained cyclist, concluding that years of experience and specific training does not improve efficiency.[27] It was long thought that training had no effect on GE. However, as explained by Hopker *et al*. in their review, methodology issues were present, and they conclude that training has a positive influence on gross efficiency.[28] Pedaling technic is another important factor in the difference in GE between BM and NBM.[24] Cyclists with better pedaling technique are able to apply optimal force on the crank on the whole pedal revolution, greatly limiting the dead centers, which are, by definition, the moments without applied force.[24] Since pedaling technique influences GE, a less experienced cyclist will consume more energy to accomplish the same effort.[24] This results in a lower GE for NBM caused by their lack of experience in cycling and, therefore, likely by their less effective pedaling.

Another important finding of this study is that, in both groups, the most efficient pedaling rate is the lowest tested (60 rpm). This result is consistent with those found in other studies. Most of them state that the most efficient pedaling rate lies between 30-60 rpm.[9, 29] As Chavarren and Calbet explain, at a determined intensity, increased pedaling rate causes an increase in internal work, which provokes a decrease in GE.[9, 30, 31] This phenomenon is even more important for non-skilled cyclists, like NBM, due to their lack of pedaling technique.[29] As said before, the influence of pedaling rate on GE becomes less significant at higher intensity. Going with the present study, other studies conducted at low intensity (30-60% of $\dot{V}O_{2max}$), have found better efficiency at low pedaling rates.[9] However, Leirdal and Ettema show that experimented cyclist tends to choose a higher freely chosen pedaling rate.[24] Some studies have shown that an increase in intensity and pedaling technique results in a higher optimal pedaling rate[29] with less force needed on the crank.[32] Coast and Welch conclude on a sample of 5 participants that optimal cadence may be better for power output over 200 W and that it may be explained by acquired skill of trained cyclist used to pedal at a higher rate. Patterson and Moreno suggest that a higher pedaling rate can minimize peripheral force and potential fatigue of those muscles groups, even if it results in a higher oxygen uptake so a lower efficiency. In their 2015 study, Beneke and Alkhatib explained that an increase in cadence results in an increase in BLC. They also emphasized that variations in BLC are even greater when increasing the exercise intensity.[33] At all cadences, BLC is a robust endurance predictor.[4] Results in our study show a significant increase in BLC as cadence increases in the NBM group. BM, on the other hand, showed a more stable BLC throughout the different pedaling rates indicating that they likely were pedaling below the highest exercise intensity at which blood lactate remains stable, which is called maximal lactate steady states (MLSS). It has been shown that trained cyclists reach a higher MLSS than non-trained cyclists.[4] This difference in BLC between the groups shows that NBM have a lower oxidative capacity suggesting that anaerobic glycolysis is significantly greater during exercise. We calculated the consumed energy by measuring oxygen exchange during the tests. Since anaerobic glycolysis does not use oxygen to produce energy, it was not measured. This means that the actual energy spent to complete the test is underestimated by the measurements in the NBM group. GE is, therefore, only described from the aerobic part in the NBM group.

The results also showed some relationships between MAP/kg and low BLC at 50% of MAP. This appears plausible as both BLC and MAP are considered to be excellent cycling performance predictors.[4] In our study, the aerobic intensity ranges from 59 to 65% and 60 to 67% of $\dot{V}O_{2max}$ for BM and NBM, respectively. Trained endurance athletes with a better oxidative capacity easily push their anaerobic threshold at higher percentage of their maximum, whereas untrained athlete reach this threshold earlier and thus use their anaerobic energy production earlier relative to their maximum,[34] explaining that those with a greater MAP/kg tend to have low BLC at 50% of their MAP.

Isokinetic strength test showed that NBM had higher peak torques at 60°/s in knee flexion than BM on a maximal strength test. This can be explained by the diversity of sport practiced by NBM and thus the probable use of this group at a higher intensity than during cycling which implies very repetitive movements at an intensity far from that tested. When tested at lower intensity, there was no intergroup difference in muscle fatigability. Being a BM significantly develops aerobic capacity and GE in comparison to other sports, but knee flexors maximal strength seems less trained. However, heterogeneity of the sports practiced by our control group does not allow conclusions on training effects on knee flexors according to a particular type of sport. A more homogenous control group according to sports type and physical activity (*e.g.* professional cyclists or sedentary) would have described the maximal flexor strength training effect in BM in a more accurate way.

Few correlations between isokinetic strength test and GE at different cadences were found in BM. Many studies have shown that maximal strength training is related to potential better GE.[10-14] We presumed that maximal strength indexes like isokinetic peak torques could be correlated with GE at different cadences. The results of this study do not validate this hypothesis. Most of these studies used strength training methods using multi-joint exercises like half-squat, potentially stimulating higher muscles groups than those tested on the isokinetic device. Louis *et al*. tested trained cyclists on a leg extension device, which is very close to the position we tested on the isokinetic device, requesting a single-joint movement in an open kinetic chain. However, they did find an improved GE in older athletes whereas younger athletes did not show differences in GE after the strength training program.[12] Thus, isokinetic knee maximal strength and fatigability were not linked with GE and do not seem relevant when evaluating a cyclist performance.

Limitations of the study

The main limitation of this study relies in the comparison of GE at equivalent metabolic output but different absolute power output. External power has an influence on GE and when analyzing data from the literature, a difference of close to 1% may be explained by the fact that the protocol was tested at different absolute powers.[3, 9, 35] The larger difference found at 100 rpm argues for an intergroup difference and that maybe pedaling coordination have a role but this stays a hypothesis. This seriously alters conclusion on comparison between both groups. For practical reason, this study tested efficiency during a short time period, which does not exactly reflect the exercise usually performed by cyclists outside a laboratory. A study by Coast *et al*. followed a protocol with longer exercise period, testing the pedaling rate during 30 minutes at 85% of $\dot{V}O_{2max}$.[36] It resulted in a 60 to 80 rpm optimum cadence which tends to get closer to the preferred pedaling rate approximately calculated at 90 rpm.[36, 37] Another limitation is the sample size. However, a power calculation indicated that 8 participants per group was acceptable and our sample size was the same or slightly higher than previously published studies on the subject.[11, 12]

Conclusions

This study demonstrates that BM have a very high fitness and that a clear difference in GE, $\dot{V}O_{2max}$, BLC and MAP/kg in favor of BM and that this increased oxidative capacity can in large part be explained by differences in specific endurance training. The most efficient cadence was 60 rpm in both groups. Investigating strength indexes seem interesting to analyze cycling performance but despite being a gold standard in strength evaluation, maximum peak torque and fatigability tests on an isokinetic device (which only measures knee extensors and flexors strength) do not seem to be useful to monitor factors influencing GE in cycling whereas closed-chain multi-joint movements like squats appear to be.

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