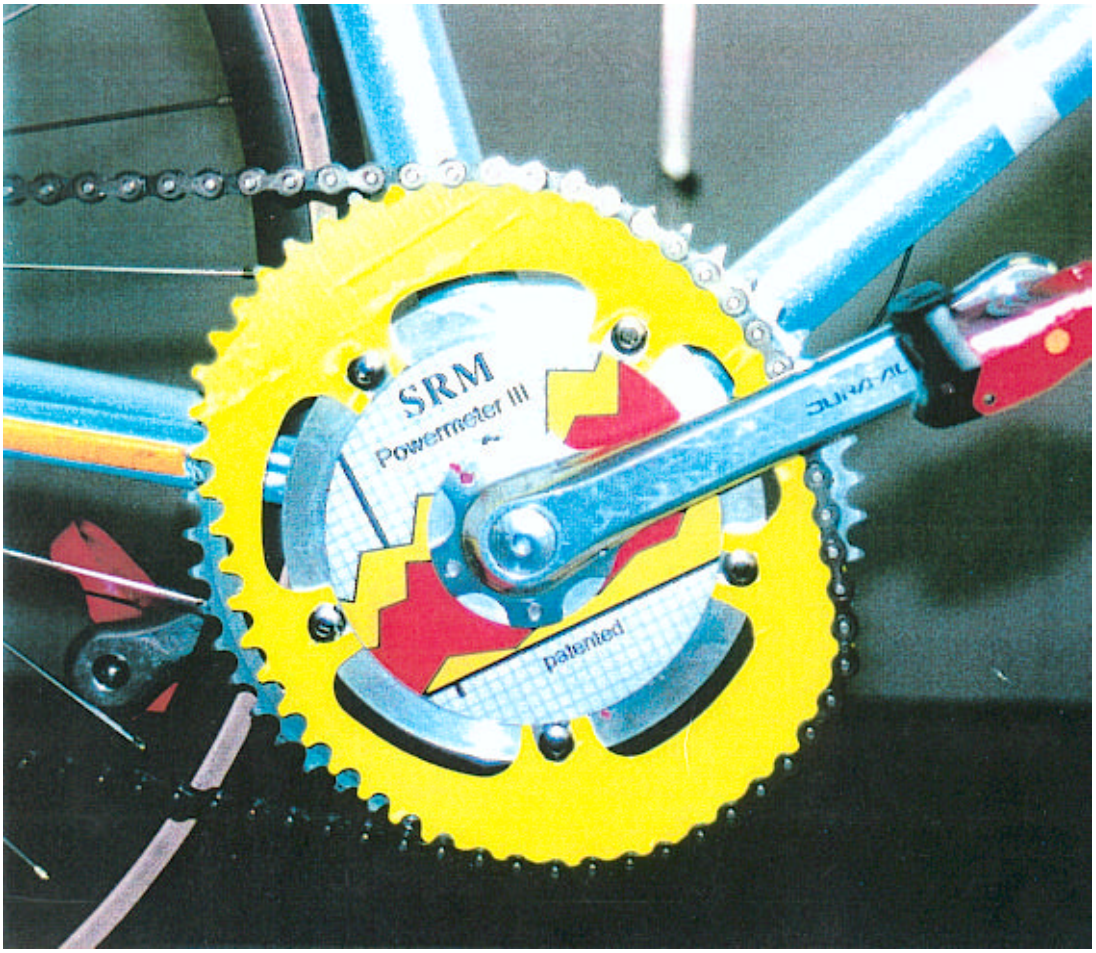
# COMPARATIVE RESEARCH
# ON
# CIRCULAR AND NON CIRCULAR
# CHAIN WHEEL



# COMPARATIVE RESEARCH ON
# CIRCULAR AND NON CIRCULAR CHAIN WHEEL

## A. LABORATORY STUDY

1. Material used

The subject stands on a bicycle adjusted in accordance with his personalised points.

This bicycle is fixed on a simulator with electromagnetic break which is regulated in power.


A dynamometric pedal equipped with 8 gauges allowing to measure the torque. The power (torque x angular speed) is non stop put up on a receiver put on the handlebars.

Other parameters like:

* Pedalling frequency (t/min)
* Move speed (km/h)
* HR (beats/min)

are stocked on a receiver too.

All these informations collected are, at the end of the experience, put in a computer.

A camera stand in front of the pedal permits to film pedalling sequences in view of a gesture quality analyse in both situations.

**Experimental protocol**

5 subjects in which:

* 4 racing cyclists of 1st category
* 1triathlet

joined in the experience. (The missing availability of our installations did not permit us to increase the size of our sample).

The alternation of the circular chain wheel and non circular chain wheel was respected in accordance with the following plan:

| | | | | |
|---|---|---|---|---|
| **Subject PI** | **NC** | **CIR** | **CIR** | **NC** |
| **Subject DA** | **CIR** | **NC** | **NC** | **CIR** |
| **Subject AG** | **NC** | **CIR** | **CIR** | **NC** |
| **Subject PR** | **CIR** | **NC** | **NC** | **CIR** |
| **Subject BE** | **NC** | **NC** | **CIR** | **NC** |

Each of these subjects have undergone two 20 minutes test series with both chain wheels, so be it:

150 w (10') then 200 w (10')
and after salvage,
175 w (10') then 225 w (10')

Subjects were recommended to respect a pedalling speed of 80 rpm which is the speed considered as optimal.

## 2. Results

The table I shows the whole results:

*Heart Rate*: in the same moving conditions (30,8 km/h) the HR is a little bit lower with the non circular chain wheel (- 2 beats/min average). However, the difference would not be significant.

The graph I represents the evolution of HR with both systems and different powers.

*Power*: power recorded at the pedal level is higher with the non circular chain wheel for the 5 subjects. The average difference observed is 6,8 watts.

The graph II represents the evolution of that power with both chain wheels at different simulated power.

*Maximum power*: the maximum power measured on the tangential strength curves (see the graph 3a, b, c, d) removed while the different test is in average higher with the non circular chain wheel (+ 4,2 daN).

The application length of the maximum power is systematically shorter than with the circular chain wheel.

On Table II are represented results for the whole subjects.

On graphs (3a, b, c, d), the average evolution of the maximum power is represented in red (circular chain wheel), in blue (non circular chain wheel) and on both sides of these average races, the variations (black straight). The breaking up around these average strength are more reduced with the non circular chain wheel.

*Surface represented by the tangential evolution strength on 360° (right leg, then left leg)*: the strength's sum of the curve applied on the right and left pedal is upper in average of 2,5 % (see table III) with the non circular chain wheel. (The included units in the tables are arbitrary).

*Analyse of the angular variation of the pedal*: the observation picture by picture of the gesture of pedalling allowed to situate in the crank's coming down phase, and this, in the maximum pressure zone, the incline of the shoe support's strength (graph 4a, b, c, d, e).

We notice that, in accordance with the chain wheel's type, the strength's direction is not identical to such an extent of the cycle.

## 3. Discussions

For almost identical conditions:

* HR,
* Pedalling speed,
* Braking power on simulator,

The power gotten at the pedal is always higher with the non circular chain wheel.

In these same conditions, the maximum strengths exerced on the pedals are higher with the non circular chain wheel and the curves' form is different too from one system to an other one, logical repercussion of the variations of the non circular chain wheel's spoke.

The observed variations around the average curves less important with the non circular chain wheel, reveal a bigger regularity of pedalling.

Those same curves integrated give an advantage to the non circular chain wheel (+ 2,5 %). This result is theoretically significant of a better output, so that the HR is a little lower.

The graph (Fig. 5) representing some muscles intervention during the pedal revolution, show that intern and extern muscles give their maximum activity before the crank reaches the horizontal.

The picture-by-picture analyses let show important differences in the pedal's incline according to the chain wheel used. At equal muscle power, the tangential power (significant of torque) will be different and therefore the final output too.

One of the tested persons particularly appreciated the non circular chain wheel; then he presents a different foot direction at each analysed picture, very different according to the chain wheel used and near the ideal direction for the on circular chain wheel (Fig. 4).

## 4. Conclusion

Our sample's size does not permit us to analyse the results with the help of statistical tests. However, our results' tendency confirms those gotten by the "Centre de Recherches en Physiologie de Monaco". The whole results are in favour or the non circular chain wheel.

**We suppose that the space would have been bigger in some more important experimental conditions. However, our laboratory is not situated in the hospital environment, it was excluded to impose some high work's charges with no cardiologic supervision.**

An electromyography measure is necessary to compare fibres quantity used with both chain wheels. We expect a similar experimentation as soon as possible. Different tested persons, even not trained with the non circular chain wheel, were very satisfied and not disturbed with that new chain wheel.
Anyway, powers are better biased with the non circular chain wheel, and most of all, in the maximum pressure zone (phase 2, 3, 4).

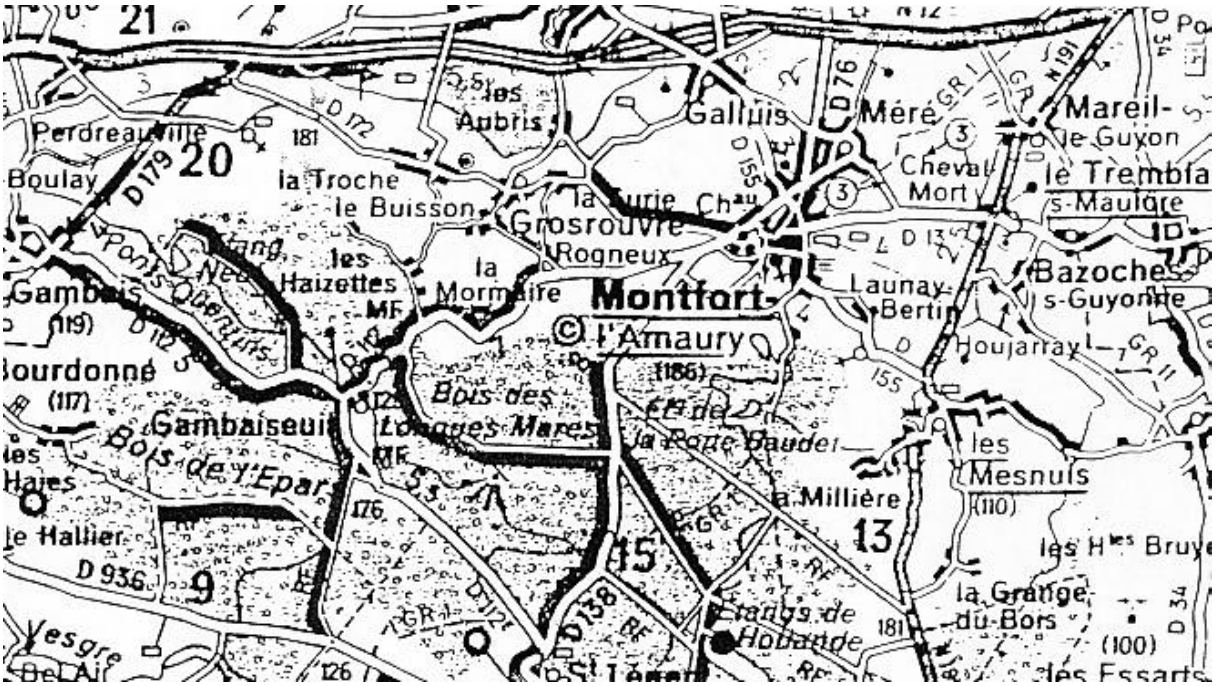
**The way to pedal is more regular avec the non circular chain wheel.**

## B. REAL SITUATION STUDY

**Tested person: Thierry MARIE**

1. Experimental circuit

The test was realized on a 16 km long circuit including an 1100 meters long hill. The circuit includes a tenth meters long flat road situated at half hill.




2. Material used

The dynamometric chain wheel used in laboratory is on Thierry MARIE's personal bicycle.

The parameters measured in laboratory are recorded and stocked in a computer fixed on the handlebars.

The table called "Fig 6" represents a record example.

3. Experimental protocol

In the morning, the tested person makes 2 circuit turns with a non circular chain wheel, and 1 turn with a circular chain wheel. This training allows the cyclist to know the new device. These data are non usable.

In the afternoon, 3 hours after lunch, the circuit is run:

- 1 time with a circular chain wheel,
- 1 time with a non circular chain wheel,

**or**

- 1 time with a non circular chain wheel,
- 1 time with a circular chain wheel.

It's recommended to use equal developments in both situations, but always stand on the 54 teeth chain wheel.

This person had to respect, particularly on a flat road, an 80 t/min pedalling rhythm.

4. Results

The following table summarises some results :

- ✓ On the whole circuit,
- ✓ On a 6300 meters long flat road,
- ✓ On a 1100 meters long hill.

| | **Power** | | **HR** | | **Rhythm** | | **Speed** | |
|---|---|---|---|---|---|---|---|---|
| | Circular | Non cir. | Circular | Non cir. | Circular | Non cir. | Circular | Non cir. |
| 16,5 km long circuit | 323 | 356 | 153 | 161 | 78,4 | 81,1 | 39,7 | 41,2 |
| 6,3 km long flat | 335 | 358 | 156 | 165 | 79,5 | 81,7 | 37,7 | 38,9 |
| 1,1 km long hill | 420 | 449 | 156 | 158 | 72,8 | 75 | 30,2 | 31,4 |

5. Results

A) *Comparison on a complete circuit*

With a non circular chain wheel:

- Speed is higher of 1,5 km/h, so +3,8 %. It means that we can win 45 seconds.
- Power is 33 watts higher, so +10,2 %.
- Heart rate is 8 beats/min higher, so +5,2 %. This HR raising can be due to:
    - *A pedalling rhythm with 2,7 t/min more than the circular chain wheel rhythm (+3,5 %);*
    - *The previous experience repercussion with the circular chain wheel. Indeed, the rest period between 2 tests is reduced; the person is confronted to a transport timetable problem.*

B) *Comparison on flat road*

We can find the same tendencies than the entire circuit, and proportions are nearly the same.

**Speed:** **+ 3,2 %**
**HR:** **+ 5,7 %**
**Power:** **+ 6,8 %**

C) *Comparison on a hill*

With the non circular chain wheel, tendencies are always the same. However, HR did not increase in the same way (only + 1,2 %).

## 6. Conclusion

**Pedalling rhythms are always more important with the non circular chain wheel. The cyclist maintained that, in the downhill slope, development was too small (54 x 12). It means that it is necessary to increase the number of teeth on the chain wheel.**

**The higher heart rate in these 3 experiences can be due to a more important pedalling rhythm because of the non circular chain wheel. Then, the cyclist should get distanced from the optimum rhythm, so about 3 %. However, physiological studies have shown that, if we get distanced from the optimal rhythm, there should happened a cardio-respiratory repercussion.**

**Results obtained on a hill test are not surprising and correspond to the "Centre de Recherche de Monaco" observations. Indeed, the non circular chain wheel would be more efficient if the power increases.**

| | CIRCULAR CHAIN WHEEL | | | | NON CIRCULAR CHAIN WHEEL | | | |
|---|---|---|---|---|---|---|---|---|
| | Chain wheel | Heart Rate (bat. min-1) | Rhythm (t.min-1) | Speed (km.h-1) | Chain wheel | Heart Rate (bat. min-1) | Rhythm (t.min-1) | Speed (km.h-1) |
| Average person 1 | 157,0 | 109,0 | 82,8 | 31,6 | 168,7 | 110,0 | 82,9 | 31,7 |
| Waste person 1 | 38,7 | 11,0 | 0,6 | 0,2 | 38,1 | 10,9 | 0,3 | 0,1 |
| Average person 2 | 186,5 | 122,9 | 78,6 | 30,0 | 199,5 | 124,1 | 78,6 | 30,0 |
| Waste person 2 | 40,5 | 12,1 | 2,7 | 1,1 | 51,7 | 15,5 | 1,2 | 0,5 |
| Average person 3 | 172,1 | 123,9 | 80,7 | 30,9 | 177,0 | 120,9 | 80,5 | 30,8 |
| Waste person 3 | 38,7 | 9,3 | 0,5 | 0,2 | 38,8 | 8,1 | 0,3 | 0,1 |
| Average person 4 | 187,5 | 115,9 | 80,6 | 30,8 | 190,8 | 107,8 | 80,2 | 30,7 |
| Waste person 4 | 40,9 | 9,2 | 0,2 | 0,1 | 41,7 | 14,1 | 0,2 | 0,1 |
| Average person 5 | 189,4 | 111,4 | 80,4 | 30,7 | 192,1 | 112,8 | 80,6 | 30,8 |
| Waste person 5 | 39,5 | 8,8 | 0,4 | 0,2 | 39,0 | 10,8 | 0,4 | 0,1 |
| **Average every person** | **178,1** | **116,3** | **80,7** | **30,8** | **184,9** | **114,6** | **80,6** | **30,8** |
| **Waste every person** | **37,2** | **10,7** | **1,6** | **0,6** | **38,2** | **12,2** | **1,4** | **0,5** |

TABLE 1

| | | CIRCULAR CHAIN WHEEL | | | NON CIRCULAR CHAIN WHEEL | | |
|---|---|---|---|---|---|---|---|
| Watt power | Persons | Max Power Right leg *(daN)* | Max Power Left leg *(daN)* | Max Power Average *(daN)* | Max Power Right leg *(daN)* | Max Power Left leg *(daN)* | Max Power Average *(daN)* |
| **175** | **1** | 19,2 | 17,7 | 18,4 | 24,8 | 22,2 | 23,5 |
| **225** | **2** | 27,2 | 22,2 | 24,7 | 29,4 | 26,4 | 27,9 |
| **225** | **3** | 25,0 | 25,0 | 25,0 | 30,2 | 28,4 | 29,3 |
| **225** | **5** | 22,5 | 24,0 | 23,2 | 27,0 | 27,6 | 27,3 |
| | **Every person** | **23,5** | **22,2** | **22,8** | **27,8** | **26,1** | **27** |

Tableau II

## CIRCULAR AND NON CIRCULAR CHAIN WHEEL MAXIMUM COMPARISON POWER

## CHAIN WHEEL RIGHT AND LEFT POWER REPRESENTED SURFACE

*(Integrated units are arbitrary)*

| | CIRCULAR CHAIN WHEEL | | | NON CIRCULAR CHAIN WHEEL | | |
|---|---|---|---|---|---|---|
| | Right leg | Left leg | Average RL & LL | Right leg | Left leg | Average RL & LL |
| **Person 1** | 162952 | 151801 | 314753 | 180364 | 145211 | 325575 |
| **Person 2** | 212162 | 173491 | 385653 | 209398 | 188897 | 398295 |
| **Person 3** | 181895 | 200533 | 382428 | 201784 | 189493 | 391277 |
| **Person 5** | 186837 | 204603 | 391440 | 193952 | 200917 | 394869 |
| **General Average** | **185961** | **182607** | **368568** | **196374** | **181129** | 377504 |

Tableau III

AG 2

circulaire

1550
1465
1380
1295
1210
1125
1040
955
870
785
700

0 30 60 90 120 150 180 210 240 270 300 330 360

harmonic

1600
1510
1420
1330
1240
1150
1060
970
880
790
700

0 30 60 90 120 150 180 210 240 270 300 330 360

Winkel [Grad]

Fig 3a

BE 1

circulaire

Frequenz [Hz]

1300
1225
1150
1075
1000
925
850
775
700
625
550

0 30 60 90 120 150 180 210 240 270 300 330 360

harmonic

Frequenz [Hz]

1500
1405
1310
1215
1120
1025
930
835
740
645
550

0 30 60 90 120 150 180 210 240 270 300 330 360

Winkel [Grad]

Fig 35

PI 5

circulaire

Frequenz [Hz]

1450
1375
1300
1225
1150
1075
1000
925
850
775
700

0 30 60 90 120 150 180 210 240 270 300 330 360

harmonic

1650
1545
1440
1335
1230
1125
1020
915
810
705
600

0 30 60 90 120 150 180 210 240 270 300 330 360

Winkel [Grad]

Fig 3c

PR 3

circulaire

Frequenz [Hz]

1600
1500
1400
1300
1200
1100
1000
900
800
700
600

0 30 60 90 120 150 180 210 240 270 300 330 360

harmonic

Frequenz [Hz]

1850
1725
1600
1475
1350
1225
1100
975
850
725
600

0 30 60 90 120 150 180 210 240 270 300 330 360

Winkel [Grad]

Fig 3d

PMH

BE

1

2

3

4

5

6

circulaire

harmonic



Fig 40

PMH

AG

1

2

3

4

5

6

circulaire

harmonic



Fig 4b

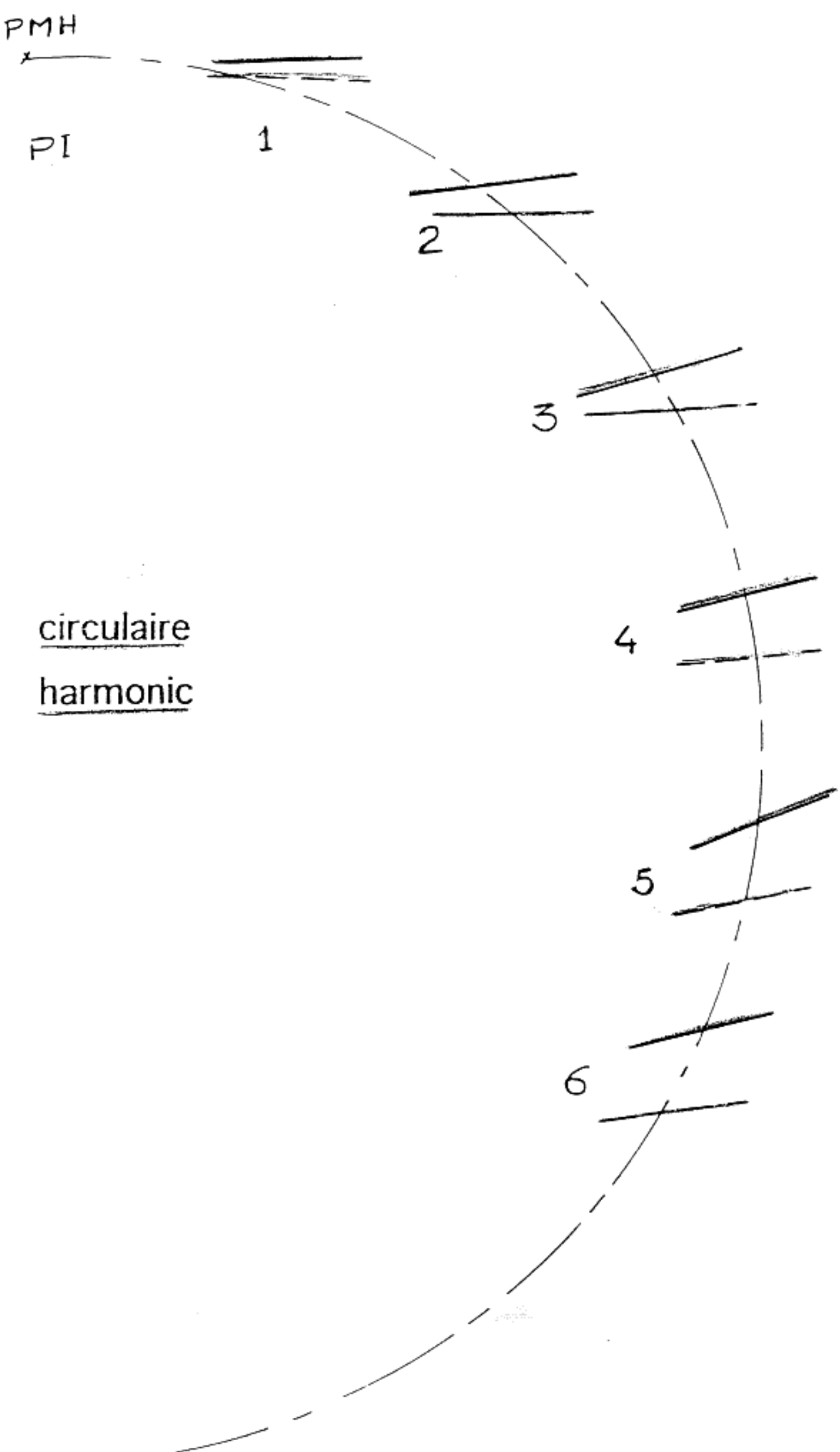





Fig 4c

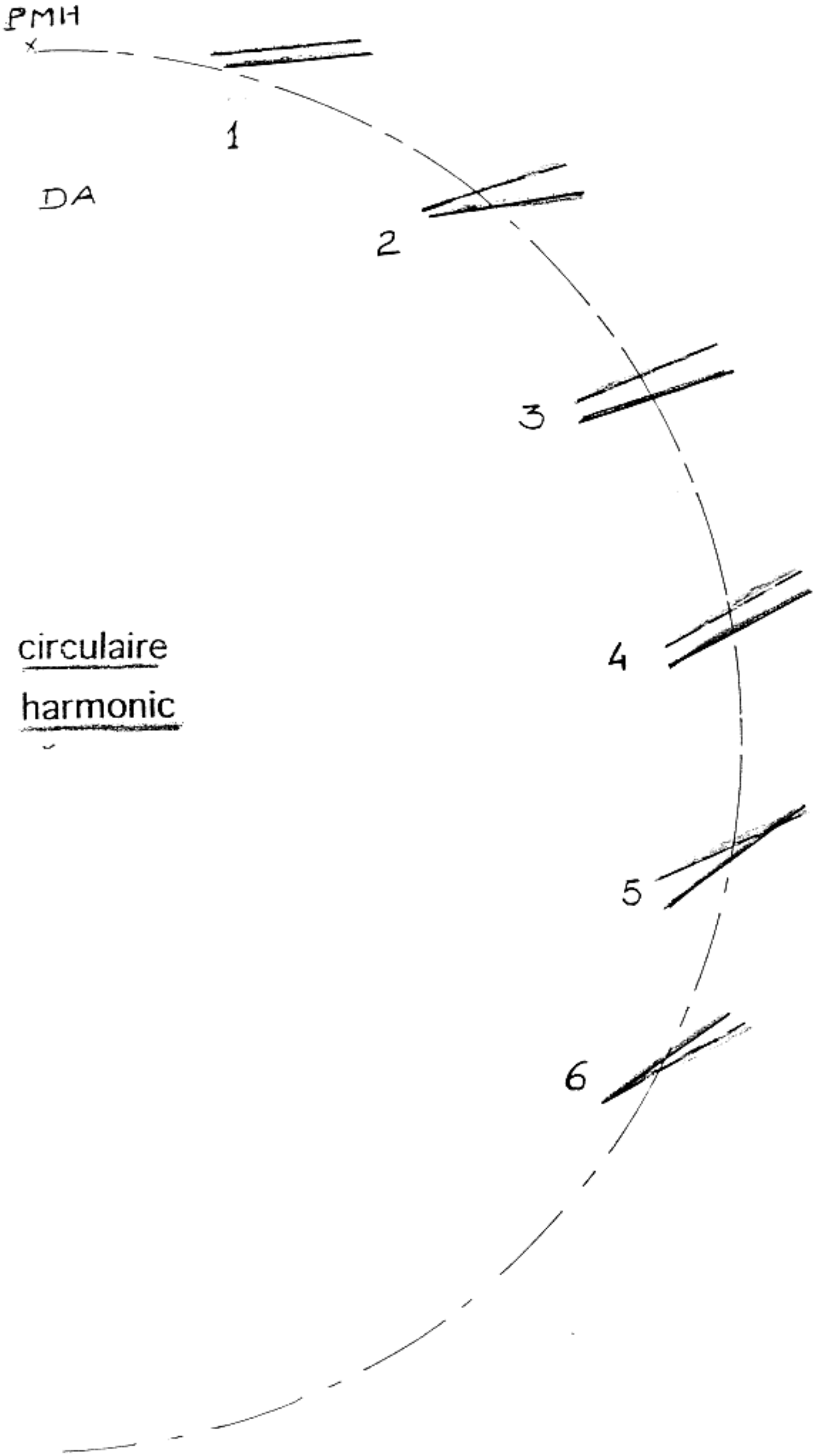





Fig 4 d

PMH

PR

1

2

3

4

5

6

circulaire

harmonic



Fig 4e

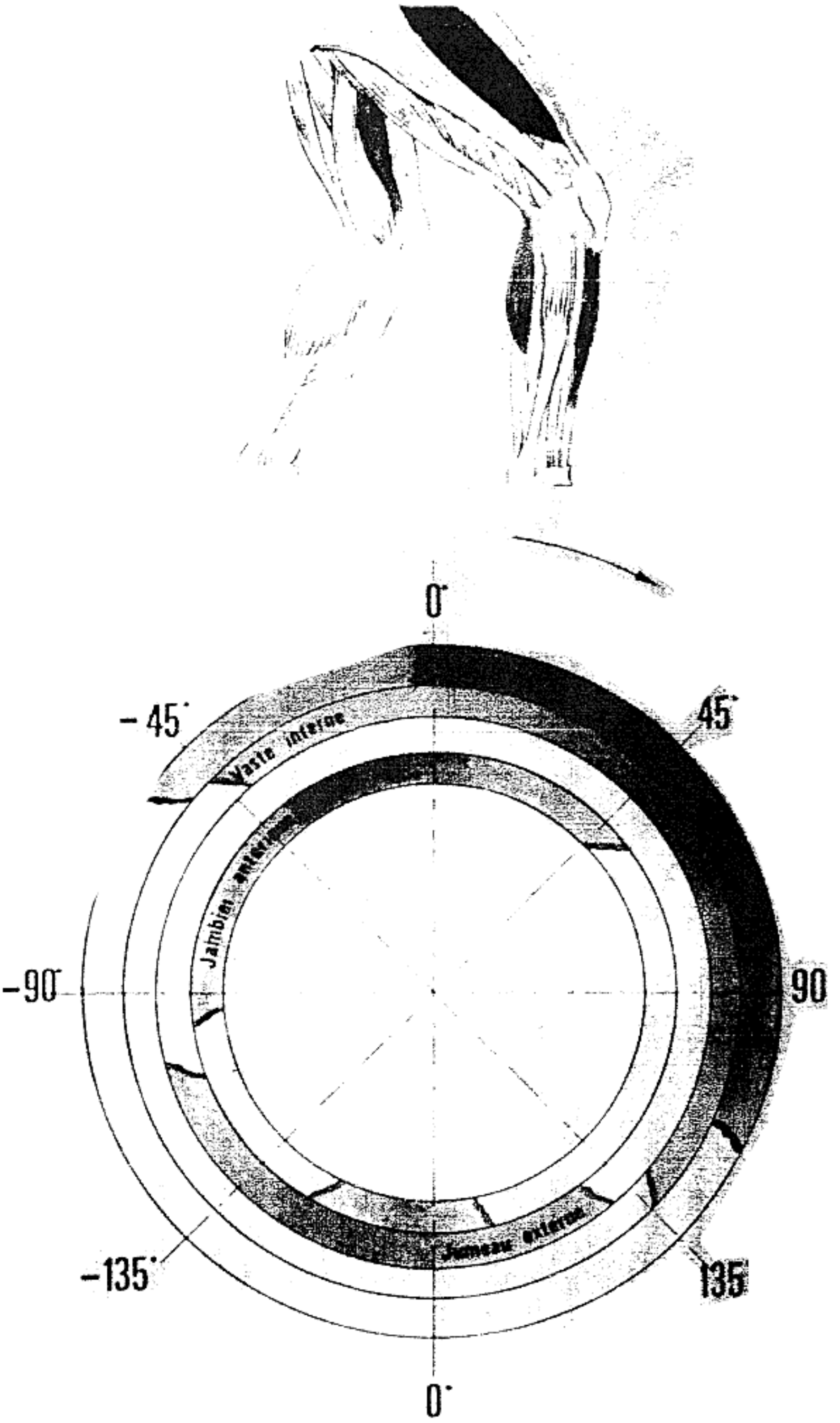
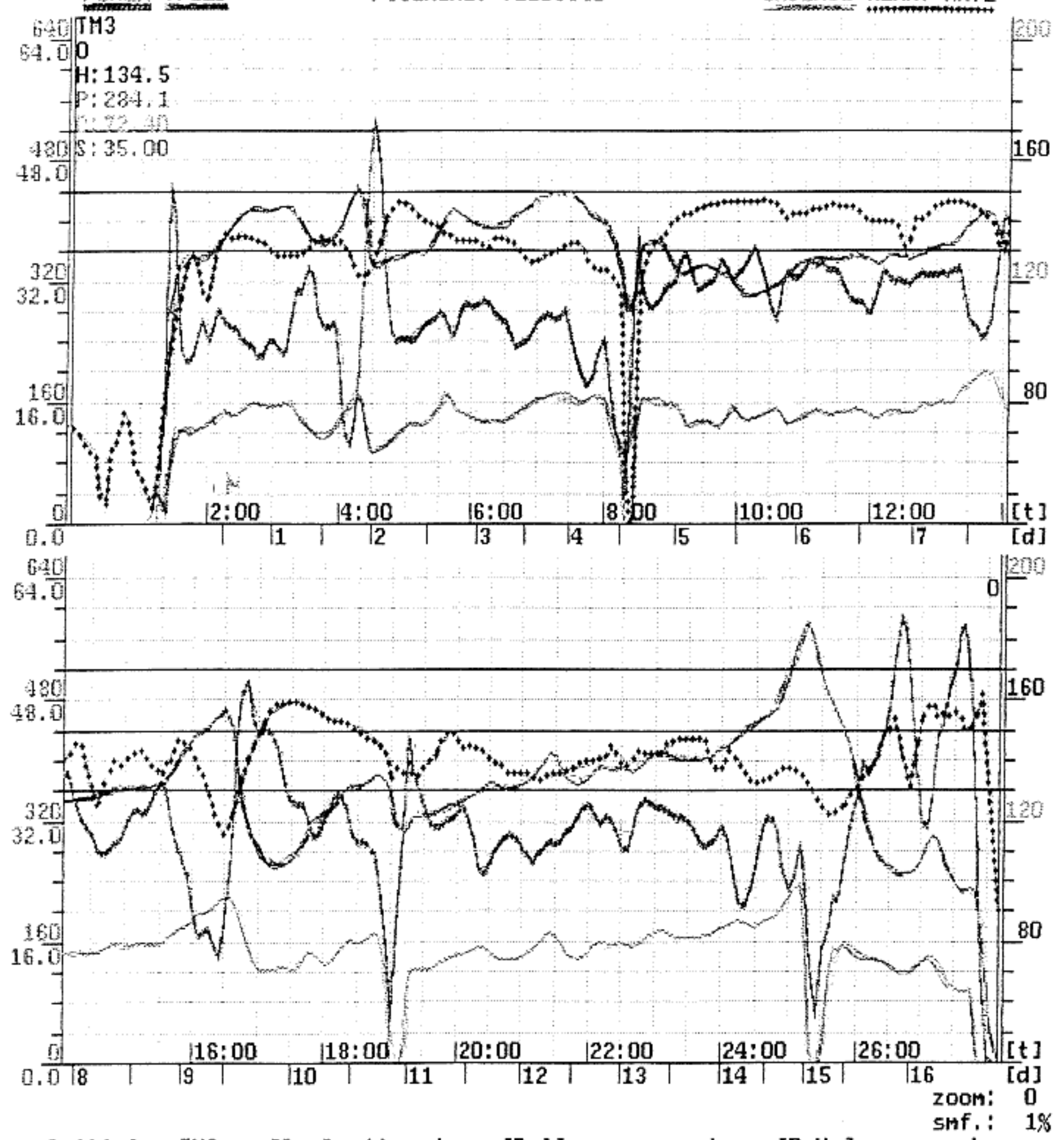



Fig : 4 _ INTERVENTION MUSCULAIRE AU COURS D'UNE RÉVOLUTION DU PÉDALIER _ Physio RNUR

POWER SPEED  Filename: T220394C  CADENCE HEART RATE




zoom: 0
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Initials: TM3  [Ins] add marker  [Del] remove marker  [PgUp] zoom marker

Fig 6