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**Peripheral Insulin Resistance Predicts Liver Damage in Non-Diabetic Subjects with Non Alcoholic Fatty Liver Disease**

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Complete List of Authors:	<p>Rosso, Chiara; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Mezzabotta, Lavinia; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Gaggini, Melania; Institute of Clinical Physiology-CNR, Cardiometabolic Risk Laboratory, Pisa, Italy; Dipartimento di Patologia Chirurgica, Molecolare Medica e di Area Critica, Università di Pisa, Italy,          Salamone, Federico; University of Catania, Department of Internal Medicine, Catania, Italy          Gambino, Roberto; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Marengo, Andrea; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Saba, Francesca; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Vanni, Ester; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Jouness, Rami; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Saponaro, Chiara; Institute of Clinical Physiology-CNR, Cardiometabolic Risk Laboratory, Pisa, Italy; Dipartimento di Biotecnologie, Chimica e Farmacia, University of Siena, Italy,          Buzzigoli, Emma; Institute of Clinical Physiology-CNR, Cardiometabolic Risk Laboratory, Pisa, Italy          Caviglia, Gian Paolo; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy          Abate, Maria; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy,          Smedile, Antonina; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy,          Rizzetto, Mario; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy,          Cassader, Maurizio; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy,          Gastaldelli, Amalia; Institute of Clinical Physiology-CNR, Cardiometabolic Risk Laboratory, Pisa, Italy          Bugianesi, Elisaetta; Division of Gastro-Hepatology, Department of Internal Medicine, San Giovanni Battista Hospital, University of Torino, Italy,</p>

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4 **Alcoholic Fatty Liver Disease**  
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9 **Short title: OGIS and liver fibrosis in NAFLD**  
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13 <sup>1</sup>Chiara Rosso, <sup>1</sup>Lavinia Mezzabotta, <sup>3, 4</sup>Melania Gaggini, <sup>2</sup>Federico Salamone, <sup>1</sup>Roberto Gambino,  
14 <sup>1</sup>Andrea Marengo, <sup>1</sup>Francesca Saba, <sup>1</sup>Ester Vanni, <sup>1</sup>Rami I.K. Jouness, <sup>3,5</sup>Chiara Saponaro, <sup>3</sup>Emma  
15 Buzzigoli, <sup>1</sup>Gian Paolo Caviglia, <sup>1</sup>Maria Lorena Abate, <sup>1</sup>Antonina Smedile, <sup>1</sup>Mario Rizzetto,  
16 <sup>1</sup>Maurizio Cassader, <sup>3</sup>Amalia Gastaldelli and <sup>1</sup>Elisabetta Bugianesi.  
17  
18

19  
20 <sup>1</sup>Division of Gastroenterology and Hepatology and Lab. of Diabetology, Dept. of Medical Sciences,  
21 University of Turin, Turin, Italy; , <sup>2</sup> Division of Gastroenterology, Azienda Sanitaria Provinciale di  
22 Catania, Catania, Italy.<sup>3</sup> Cardiometabolic Risk Unit, Institute of Clinical Physiology, CNR, Pisa,  
23 Italy, <sup>4</sup>University of Pisa, Italy, <sup>5</sup> University of Siena, Italy.  
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35 **Correspondence to:**

36  
37 Amalia Gastaldelli, PhD,  
38 Head of Cardiometabolic Risk Unit  
39 Institute of Clinical Physiology, CNR  
40 via Moruzzi 1 56100 Pisa Italy  
41 tel +39 050 3152679/80  
42 fax +39 050 3152166  
43 email [amalia@ifc.cnr.it](mailto:amalia@ifc.cnr.it)  
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13 **Abbreviations:** ALT, alanine aminotransferase; AST, aspartate aminotransferase; AUC, area under  
14 the receiver operating curve; BIGTT,  $\beta$ -cell function, insulin sensitivity index derived from oral  
15 glucose tolerance test; BMI, body mass index; DM, type 2 diabetes mellitus; EGP, endogenous  
16 glucose production; eMCR<sup>dem</sup>, metabolic clearance rate estimation with (dem) or without (nodem)  
17 demographic parameters; FIRI, fasting insulin resistance index; HDL-Chol, high density lipoprotein  
18 cholesterol; FPI, fasting plasma insulin; G, glucose; HepIR-DF, De Fronzo hepatic insulin  
19 resistance index; HIRi, hepatic insulin resistance index derived from tracer analysis; HOMA,  
20 homeostasis model assessment; FPI, fasting plasma insulin; IGR, insulin to glucose ratio; IR,  
21 insulin resistance; ISI, insulin sensitivity index; LIRI, liver insulin resistance index; NFS, non-  
22 alcoholic fatty liver disease fibrosis score; OGIS, oral glucose insulin sensitivity index; PLT,  
23 platelets; QUICKI, quantitative insulin sensitivity check index; SD, standard deviation; SiOGTT,  
24 insulin sensitivity index derived from oral glucose tolerance test.

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**Abstract**

**BACKGROUND & AIMS.** Surrogate indexes of insulin resistance/sensitivity (IR/IS) are widely used in Non Alcoholic Fatty Liver Disease (NAFLD) although they have never been validated in this population. We aimed to validate the available indexes in NAFLD subjects and to test their ability to predict liver damage and hepatic/ metabolic complications.

**METHODS.** Surrogate indexes were validated by tracer technique (D2-glucose and U-13C-glucose) in the basal state and during an Oral Glucose Tolerance Test (OGTT). The best performing indexes were used in an independent cohort of 145 non-diabetic NAFLD subjects to identify liver damage (fibrosis and NASH) and the longitudinal risk of hepatic/metabolic complications.

**RESULTS.** In the validation NAFLD cohort, HOMA-IR, IGR and ISI Stumvoll had the best association with hepatic IR, while peripheral IS was most significantly related to OGIS, ISI Stumvoll and  $eMCR^{nodem}$ . In the independent cohort, only OGTT derived indexes were associated with liver damage and OGIS was the best predictor of moderate/severe fibrosis (OR=0.70, 95% CI=0.58-0.85,  $P=0.0002$ ) and NASH (OR=0.75, 95% CI=0.63-0.90,  $P=0.002$ ). Both OGIS and NAFLD Fibrosis Score (NFS) identified advanced (F3/F4) fibrosis, but only OGIS was able to discriminate F2 from F3/F4 ( $P<0.003$ ). After an average follow up of  $112 \pm 42$  months,  $OGIS \leq 10$  mg/Kg min predicted all the liver-related complications, while  $NFS < -1.455$  only 20% of them. OGIS was also inversely related with the risk of metabolic events (OR 0.66, 95% CI 0.48-0.90,  $P=0.0096$ ).

**CONCLUSIONS.** OGIS is associated with peripheral IS in NAFLD and is inversely associated with an increased risk of advanced liver damage and metabolic complications in non-diabetic subjects with NAFLD.

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3 Non-alcoholic Fatty Liver Disease (NAFLD) embraces a spectrum of liver damage ranging from  
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5 isolated hepatic triglyceride accumulation (steatosis) through hepatic triglyceride accumulation plus  
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7 inflammation (non-alcoholic steatohepatitis, NASH) [1] ultimately progressing to fibrosis/cirrhosis  
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9 and potentially hepatocellular carcinoma. [2-4] NAFLD has become the most common cause of  
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11 chronic liver disease in the Western countries [5] owing to increasing rates of obesity and diabetes  
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13 in both adult and childhood [6-9] and one of the top concerns for hepato-gastroenterologists and  
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15 endocrinologists due to its potential hepatic and metabolic complications. [10] An increasing  
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17 number of features of the metabolic syndrome (MS), particularly type 2 diabetes (DM) and obesity,  
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19 are risk factors for the presence of NASH [11] and are important phenotype reflections of insulin  
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21 resistance (IR), one of the main pathogenic mechanisms for the onset and progression of  
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23 NAFLD.[12-13] In clinical practice, this translates into the wide use of HOMA-IR as a screening  
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25 tool to detect IR in NAFLD [14] and in the development of several algorithms for the non-invasive  
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27 prediction of severe liver damage based on multiple components of the MS [15-16].  
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34 HOMA-IR is a rather crude index reflecting the final effects of hepatic and peripheral IR on fasting  
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36 glucose homeostasis [17], but from the physiological point of view discerning the sites of IR is not  
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38 trivial. Insulin resistance in the skeletal muscle (or peripheral IR) is defined as a lower than  
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40 expected effect of insulin on glucose disposal by the muscle, leading to hyperglycemia and  
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42 compensatory hyperinsulinemia and favoring de novo lipogenesis (DNL) in the liver. Peripheral IR  
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44 is tightly linked to IR in the adipose tissue (ARi), i.e. impaired suppression of lipolysis and  
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46 increased fatty acid flux from the adipocytes to other organs, including the liver.[18] In the liver IR  
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48 leads to impaired suppression of glucose production and high glucose as well as insulin levels, thus  
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50 setting up a vicious cycle. While the association between ARi and liver damage has been recently  
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52 established, the relative role of hepatic and peripheral IR is currently unclear. [18,19-21]  
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57 Techniques to directly measure insulin resistance/sensitivity (IR/IS) are time-consuming, expensive  
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59 and often unavailable in daily routine; therefore, more simple tests have been developed based on  
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insulin and/or glucose levels in the fasted state [22-27] or during an oral glucose tolerance test

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3 (OGTT) combined with other metabolic and anthropometric parameters. [28-35] Although the use  
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5 of surrogate indexes of IR is widely performed in NAFLD patients, none of them has been validated  
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7 in this population against a golden standard for the assessment of peripheral and hepatic IR so far.  
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10 Some of these indexes (HOMA-IR, OGIS) have also been associated with increased liver damage in  
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12 NAFLD,[13,36] but a comparison with the non-invasive algorithms for the detection of NASH or  
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14 fibrosis has never been made. The NAFLD fibrosis score (NFS) is currently the best validated score  
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16 for the prediction of advanced fibrosis, both in cross sectional and longitudinal cohorts,[15,37] but  
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18 its performance is linked to the presence of obesity and diabetes and may be unsatisfactory in the  
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20 absence of one or both these variables.  
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24 Thus, the aim of this study is two-fold: (1) to evaluate the diagnostic accuracy of the surrogate  
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26 indexes of IR/IS by comparison with state-of-the-art technique in NAFLD patients and (2) to test  
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28 the best IR/IS indexes in an independent cohort of non-diabetic NAFLD subjects for the prediction  
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30 of histological liver damage and disease progression in comparison with NFS.  
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## Patients and Methods

### i. Validation of the Diagnostic Accuracy of the Surrogate Indexes of Insulin Resistance/Insulin Sensitivity

#### *Subjects and Study Design.*

In twenty-two non-diabetic subjects with biopsy-proven NAFLD, *in vivo* hepatic and peripheral IR were assessed by stable isotopes technique in the fasting state and during a 4-hours oral glucose load (OGTT). Eleven healthy subjects matched by age, sex and BMI served as controls. All of them had normal liver enzymes, normal liver at US-scan and low probability of hepatic fat according to non-invasive indexes (Fatty liver Index < 20 and NAFLD liver fat Score > 1.257). All experiments were performed after an overnight fast. A primed-continuous infusion of D2-glucose (bolus 22  $\mu\text{mol/kg}$ , infusion rate 0.22  $\mu\text{mol/kg min}$ ), to assess Endogenous Glucose Production (EGP), was delivered for approximately 4 hours, i.e., 2 hours in the fasting state and 2 hours after administration of a 75 g glucose load enriched with U-13C-glucose to determine glucose clearance.[35, 38]

#### *Analytical Methods and Calculations.*

Serum glucose was measured by the glucose oxidase method (Sentinel, Milan, Italy). Triglycerides and total-cholesterol (Chol) were performed by enzymatic colorimetric assays (Sentinel, Milan, Italy). High Density Lipoprotein-Chol (HDL-Chol) was determined by enzymatic colorimetric assay after precipitation of low density lipoprotein (LDL) and very low density lipoprotein (VLDL). LDL-Chol was measured with a standardized homogeneous enzymatic colorimetric method in order to avoid triglycerides effects on LDL determination (Sentinel, Milan, Italy).

Tracers enrichments of 6,6-2H-glucose and U-13C-glucose were determined by a gaschromatography-mass spectrometry system (Agilent 5975, Palo Alto, CA), selectively monitoring ions at m/z 200, 201, 202 and 205 and expressed as tracer/tracee ratios as previously described.[12, 38]

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3 Metabolic indexes derived from tracers analysis included the following: in the fasting state,  
4 hepaticIR (HIRi) was calculated as the product [fasting EGP x Fasting Plasma Insulin]; during the  
5 OGTT, peripheral insulin sensitivity was derived from glucose clearance as [EGP/Glucose  
6 concentration]. [12, 35, 38]  
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12 Surrogate indexes of IR/IS were calculated according to published formulas (Supplementary table  
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15 1).

## 16 17 18 19 20 **ii. Association of Surrogate Indexes of Insulin Resistance/Sensitivity with Liver Damage**

### 21 22 *Subjects and Study Design*

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24 An independent cohort of 145 consecutive NAFLD patients was considered to examine the relation  
25 of the best performing indexes with the histological liver damage. Patients were selected from a  
26 prospectively built database including biopsy-proven NAFLD patients, recruited since 2000 at the  
27 GI Division of the University Hospital of Torino, based on the following criteria: absence of DM,  
28 absence of overt cirrhosis, BMI<35 and liver biopsy performed before 2007 in order to have a  
29 follow up long enough to detect liver related and metabolic complications. One hundred and sixty-  
30 six patients met the above mentioned criteria. Starting in 2001, a standard 2-h 75g OGTT was part  
31 of the investigation protocol in patients without known diabetes; the tests had been performed at the  
32 time of liver biopsies ( $\pm$  1 month) and blood samples were collected at 0, 30, 60, 90, 120 and 180  
33 min for the measurement of plasma glucose and insulin levels. Nine patients were further excluded  
34 because OGTT was not performed according to the above mentioned protocol, therefore the  
35 independent cohort initially included 157 patients. As OGTT newly diagnosed DM in 12 of them,  
36 we excluded these patients from the analysis, that was finally carried out in 145 NAFLD subjects.  
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53 All patients had been previously diagnosed NAFLD based on the following criteria: (1) elevated  
54 aminotransferases for at least 6 months; (2) liver biopsy showing changes consistent with NAFLD;  
55 and (3) exclusion of other etiologies, including viral, autoimmune, cholestatic, genetic, metabolic,  
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3 alcoholic, or drug-induced liver diseases. All patients had current and past consumption of ethanol  
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5 less than 20 g per day on direct questioning of both the patients and a close relative.  
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8 A complete medical history and physical examination had been undertaken. Clinical and  
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10 anthropometric data were collected at the time of liver biopsy. BMI was calculated on the basis of  
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12 weight (in kilograms) and height (in meters) and subjects were classified as normal weight (BMI,  
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14 18.5-24.9 kg/m<sup>2</sup>), overweight (BMI 25-29.9) and obese ( $\geq 30$ ). Waist circumference (to the nearest  
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16 half centimeter) was measured at the midpoint between the lower border of the ribcage and the iliac  
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18 crest. Laboratory investigations included routine liver biochemistry (alanine-aminotransferase  
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20 [ALT] and aspartate-aminotransferase [AST] levels, total bilirubin, albumin, alkaline phosphatase,  
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22 and gamma glutamyltranspeptidase), complete blood count, fasting glucose, fasting insulin, total  
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24 cholesterol, HDL-Chol and total triglycerides.  
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29 The presence of the MS was detected according to the presence of any three out of five components  
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31 (waist circumference >94 cm for men and >80 cm for women; fasting blood glucose >100 mg/dl;  
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33 triglycerides >150 mg/dl or under treatment; blood pressure >130/85 mm Hg or under treatment;  
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35 and HDL cholesterol <40 mg/dl in men or <50 mg/dl in women).[39]  
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38 The NAFLD patients participated in the tracers study after signing an informed consent. All the  
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40 other investigations were carried out during regular follow-up of NAFLD patients, according to  
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42 specific protocols, and all patients had given their consent for including their personal data in the  
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44 database. The study was approved by the ethics committee of the University Hospital San Giovanni  
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46 Battista of Torino and was in accordance with the Helsinki Declaration.  
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### 50 51 52 53 **Liver Histology**

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55 Liver biopsies were stained with hematoxylin and eosin, Masson's trichrome and special stains for  
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57 iron and copper and were read by a single liver pathologist. All biopsies were of appropriate size  
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59 and included enough portal tracts for a confident pathological grading and staging of the  
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histological features. Histological features of NAFLD, i.e. steatosis, inflammation, hepatocyte

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3 ballooning, and fibrosis, were scored as according to Kleiner et al.[40] NASH was defined by the  
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5 local pathologist according to the joint presence of steatosis, hepatocyte ballooning and lobular  
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7 inflammation with or without fibrosis.  
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### 10 11 12 **Statistical Analysis**

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15 Data are reported as mean and standard deviation (SD) for continuous normal variables or number  
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17 and percentage (%) for categorical variables. Comparisons between groups were performed using  
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19 the two-tailed Student's *t*-test for normal continuous variables and the Mann-Whitney non-  
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21 parametric test for non-normal continuous variables. For categorical data, the Fisher exact test or  
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23 the  $\chi$ -square test were used as appropriate.  
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27 Logistic regression analysis was performed to identify the better IR/IS surrogate indexes able to  
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29 predict  $F \geq 2$  and histological diagnosis of NASH. All the analyses were adjusted for age, sex and  
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31 BMI. To evaluate the performance of both OGIS and NFS in discriminating  $F \geq 2$ , Receiver  
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33 Operating Curves (ROC) analysis was computed. Cox regression was used to assess the effects of  
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35 OGIS and NFS on the metabolic events development probability.  
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39 Dot plots were used to represent the distribution of liver-related and metabolic events at follow up  
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41 according to OGIS and NFS. Values of  $P < 0.05$  were considered statistically significant. All  
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43 calculations were performed with MedCalc® Software bvba version 12 (Mariakerke, Belgium).  
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## Results

### *Baseline Characteristics of the Validation Cohort and of the Independent Cohort of NAFLD*

#### *Subjects*

Clinical, biochemical and histological data of the validation cohort (n=22) and of the independent cohort (n=145) are reported in Table 1. The two cohorts were similar with regard to age, gender, BMI, liver function test, metabolic profile and liver histology (steatosis, fibrosis and NAS score), although a diagnosis of NASH was more frequent in the validation cohort. In the independent cohort of non-diabetic NAFLD the prevalence of obesity was low (19%) but central obesity was found in half the population and was the most common metabolic abnormality followed by hypertriglyceridemia (26%) and elevated fasting glucose (25%). Only 16% of the subjects met the criteria for diagnosis of the metabolic syndrome; nonetheless, 44% had at least two features and 76% at least one. HOMA-IR was  $>2.7$  in the vast majority of them (72%).

#### *Validation of Surrogate Indexes of Insulin Resistance/Insulin Sensitivity vs Direct Tracer Measurements.*

Table 2 summarizes the data from the tracer studies and all the surrogate indexes calculated in the validation cohort of NAFLD patients and in the control group. Although well matched for age, sex and BMI with controls, NAFLD subjects were characterized by increased fasting EGP and hepatic IR (HIRi) and by decreased peripheral IR (glucose clearance) assessed by tracers.

HIRi was significantly related with all the surrogate indexes except for TG/HDL-Chol, SiOGTT and HepIR DF (Supplementary Table 2), but HOMA-IR, IGR and ISI Stumvoll had the best correlation (Fig.1 A-B-C). Glucose clearance was related to the majority of the surrogate indexes as well (Supplementary Table 2), but OGIS, ISI Stumvoll and  $eMCR^{nodem}$  were the most significant (Fig.1 D-E-F). Of note, HOMA-IR and IGR are indexes of insulin resistance, while OGIS, ISI Stumvoll and  $eMCR^{nodem}$  assess insulin sensitivity and show a positive correlation with glucose clearance and a negative correlation with HIRi.

### *Surrogate Indexes Associated with Moderate/Severe Fibrosis*

Next we examined the association between all the surrogate indexes and fibrosis  $F \geq 2$  in the independent cohort of NAFLD subjects (Table 3). At univariate analysis, only the indexes based on OGTT were significantly associated with moderate/severe fibrosis, but at logistic regression, adjusted for age, sex and BMI, OGIS was the sole independent predictor, having an inverse relationship with fibrosis (OR = 0.70, 95% CI = 0.58-0.85,  $P = 0.0002$ ).

We further investigated the reason why OGTT derived indexes were correlated with fibrosis by splitting the independent cohort according to the degree of fibrosis at liver biopsy and to the presence of overweight/obesity (defined as  $BMI > 27$ ) (Figure 2). During OGTT the glucose curve was higher in subjects with moderate/severe fibrosis ( $F \geq 2$ ) independent of BMI (Fig. 2 A), while the insulin curve was similarly elevated in all NAFLD patients except for the lean ones without fibrosis who displayed the lower levels of insulin (Fig. 2 B). This pattern was not influenced by steatosis, as the glucose curve was similar in all patients independent of the degree of hepatic fat and of BMI (Panel C), suggesting a direct association between fibrosis and glucose levels during OGTT.

Last of all, we tested the reliability of NFS as predictors of fibrosis in this population without DM and compared it with that of OGIS. Overall, the degree of fibrosis was negatively associated with OGIS and positively associated with NFS (ANOVA  $< 0.0001$  and  $0.007$ , respectively), but only OGIS was able to discriminate moderate ( $F2$ ) from severe ( $F3/F4$ ) fibrosis (Figure 3 A-B). The sensitivity and specificity of the two indexes by ROC analysis are shown in Supplementary Table 3. The AUROCs were similar (Supplementary Figure 1) but, compared with NFS, OGIS had a better PPV and a worse NPV. At logistic regression analysis both indexes significantly predicted moderate/severe fibrosis, but the association was more meaningful with OGIS (Supplementary Table 4). Patients with lower values of OGIS had a 31% increased risk of significant fibrosis.

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### *Surrogate Indexes Associated with Diagnosis of NASH*

The same analysis were performed in order to examine the relationship between all the surrogate indexes and the diagnosis of NASH. Once again, only indexes derived from OGTT (OGIS, SiOGTT, BIGTT, eMCR<sup>dem</sup> and eMCR<sup>nodem</sup>) had a significant association with NASH and OGIS was the best predictor at logistic regression analysis (OR = 0.75, 95% CI = 0.63-0.90,  $P = 0.0021$ ) (Table 4).

### *Long-Term Outcomes Based on OGIS and NAFLD Fibrosis Score risk categories*

Follow up data were available in most of the study subjects. Five of the 13 patients lost had an histological diagnosis of simple fatty liver (SFL) and had been referred back to their GP, the remaining had F1/F2 fibrosis (n=6) and F3 (n=2). Not unexpectedly, after an average follow up of  $112 \pm 42$  months (range 42-240), the number of liver-related and metabolically-related events was very low in this cohort. Liver-related events developed in 5 subjects, all with F3/F4 fibrosis at index biopsy: only one patient died from sudden acute decompensation, one developed HCC, one encephalopathy and ascites and two thrombocytopenia that prompted for a second liver biopsy, documenting in both cases a transition from F3 to F4. Other complications developed in 20 subjects, including metabolically-related in 12 of them (diabetes in 6, and cardiovascular events in 6) and non-liver cancers in 3 of them. Besides the mentioned liver-related death, the only other one was due to hemorrhagic stroke.

We used the average value of OGIS in the control group of the tracers studies as a cut-off .  $OGIS \leq 10$  correctly identified all the subjects who developed liver-related events at follow up (Figure 4 A, left). Further, OGIS properly identified the development of diabetes in 5/6 and of cardiovascular complications in 4/6 cases (Figure 4 A, right).

On the contrary, only 1 liver-related event was correctly identified by NFS according to published cut-offs (Figure 4, Panel B left). Most subjects (85%) with severe fibrosis (F3/F4) fell into the

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3 “indeterminate” or “not-significant” fibrosis category, including 17% of severe fibrosis incorrectly  
4 classified as “not-significant”.  
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8 As expected for the low number of cases, none of the two indexes were predictors of liver events at  
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10 Cox regression analysis. However, lower values of OGIS significantly predicted metabolic events  
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12 (OR 0.66, 95% CI 0.48-0.90, P=0.0096).  
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## 16 17 **Discussion**

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19 The results of this study have significant implications, both from the pathophysiological and clinical  
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21 point of view. Firstly, it provides a rationale for the use of surrogate indexes of insulin  
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23 resistance/sensitivity in NAFLD patients that extends beyond the bare identification of IR, secondly  
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25 supports the role of IR *per se* as a mechanism of onset and progression of NAFLD and highlights  
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27 the unexplored relevance of peripheral IR, and lastly provides an index able to identify NAFLD  
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29 patients at risk for significant liver damage even in the absence of diabetes and overt obesity.  
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34 Although widely used in epidemiological studies of NAFLD, surrogate indexes of IR have been  
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36 validated by state-of-the-art techniques in healthy controls, obese and diabetic subjects but never in  
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38 a NAFLD population.[41] This is the first study to compare IR/IS in the liver and in the muscle in a  
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40 group of patients with NAFLD, in the absence of cofactors such as diabetes and overt obesity  
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42 (BMI>35) that greatly influence insulin sensitivity. The exclusion of diabetic subjects also comes  
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44 from the consideration that these indexes are affected by exhaustion of insulin secretion by the  
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46 pancreas, besides a questionable clinical utility. In this validation cohort, several indexes derived  
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48 from either fasting values [22-27] or OGTT sampling times [28-35] resulted valid, but HOMA-IR,  
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50 IGR and ISI Stumvoll had the best association with hepatic IR, while peripheral IS was most  
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52 significantly related to OGIS, ISI Stumvoll and eMCR<sup>nodem</sup>. HOMA-IR is the most used in  
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54 population studies for its simplicity and wide applicability and is based on fasting glucose and  
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56 insulin levels, where glucose concentration is mainly driven by hepatic glucose production. [13,22]  
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60 However, the relationship between HOMA-IR, IGR and HIRi can be affected by collinearity and in



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3 this sense the association of HIRi with OGTT-derived indexes, such as ISI Stumvoll, is certainly  
4 more meaningful. On the contrary OGIS, ISI Stumvoll and eMCR<sup>nodem</sup> mostly reflect glucose  
5 uptake by the muscle, i.e. the degree of peripheral insulin sensitivity; as such, they directly correlate  
6 with glucose clearance measured by tracers technique.  
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12 When tested in the independent cohort of NAFLD patients, the strength by which most surrogate  
13 indexes correlate with moderate/severe fibrosis at liver biopsy is similar to their correlation with  
14 IR/IS, confirming that the degree of IR *per se* is an important mechanism of onset and progression  
15 of NAFLD independent of its phenotypic expression (diabetes first). All the OGTT-derived indexes  
16 were better predictors of fibrosis and NASH, and OGIS confirms its effectiveness in identifying  
17 patients with advanced disease [12,36] even in a cohort considered at low risk. This finding raises  
18 the issue of the actual contribution of peripheral IR to the onset and progression of liver damage,  
19 beyond that already established of ARi. In particular, the association with fibrosis appears to be  
20 mediated by post-load glucose metabolism independent of BMI and of the degree of steatosis.  
21 Adipose tissue and skeletal muscle IR are tightly linked. In obese subjects with NAFLD there is an  
22 abrupt early-on decline in insulin action on skeletal muscle by increasing degrees of Ari [42-43],  
23 suggesting that skeletal muscle is rapidly affected by dysfunctional adipose tissue. Peripheral IR can  
24 independently contribute to NAFLD and NASH by changing the pattern of ingested carbohydrate  
25 from skeletal-muscle glycogen synthesis to hepatic DNL [44] via activation of sterol regulatory  
26 element binding protein 1c (SREBP1c) and carbohydrate response element binding protein  
27 (ChREBP). The contribution of DNL, which is less than 5% in healthy subjects, increases to 26% in  
28 NAFLD leading to a 3-fold higher rate of production of VLDL-triglycerides and increased lipid  
29 flux to the liver [45]. On the other side, newly synthesized fatty acids from DNL, mainly palmitic  
30 acid, are fully saturated and are more likely to promote lipotoxic injury. Evidence of this in mice  
31 was provided by recent studies demonstrating that generation of fatty acids in the liver through  
32 fructose-driven DNL was associated with endoplasmic reticulum stress and cellular injury [45-46].  
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3 The last implication is clinical: all the non-invasive indexes of fibrosis in NAFLD usually include  
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5 BMI and diabetes along with other components of the MS, supported by a burden of cross-sectional  
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7 and longitudinal data linking a worse clinical outcome to diabetes and frank obesity. Although not  
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9 designed to explore the natural history of NAFLD, this study confirms that the risk of advanced  
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11 liver damage and liver-related events is lower in the absence of these important co-factors, but  
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13 certainly not negligible. At the time of liver biopsy, half of the patients in the independent cohort  
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15 had significant ( $\geq$  F2) fibrosis and 25% had severe fibrosis; in the latter group, 15% developed  
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17 liver-related events in a range between 42 and 240 months. Remarkably, OGIS was able to  
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19 discriminate F2 from F3/4 better than NFS, which is an important goal. In fact, the main limitation  
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21 of currently available tests is that they perform best at distinguishing severe *vs.* non-severe fibrosis  
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23 but not advanced (F2-F4) or any ( $>$ F1) fibrosis *vs.* no fibrosis. However, while the negative  
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25 prognostic value of F1 is questionable, patients with F2 should be identified for a closer follow up  
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27 and possibly a pharmacological therapy. Longitudinally, all liver-related events were predicted by  
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29 OGIS  $\leq$  10, but the majority were missed by NFS. Although having a good sensitivity the NPV of  
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31 OGIS was far from excellent, but the low number of liver related events strongly influenced the  
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33 analysis and confirmation in larger cohorts is necessary. Consistent with being a quantitative  
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35 measure of insulin sensitivity, OGIS  $\leq$  10 also resulted an independent predictor of metabolic  
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37 complications, correctly identified in 75% of cases. The increased risk of prevalent and incident  
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39 diabetes linked with NAFLD is well documented across literature and requires screening  
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41 procedures, based on fasting or random blood glucose or haemoglobin A1c. In case of prediabetes  
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43 (fasting glucose, 100-126 mg/dl; HbA1c, 5.7-6.4%), a standardized 75-g OGTT is advisable [47]  
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45 and calculation of OGIS from OGTT is clinically relevant as it can add the risk of fibrosis and  
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47 NASH in these subjects.

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59 Limitations of the present study include the risk of collinearity in the validation of surrogate  
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indexes, which is more significant when comparing HIRi *vs* indexes based on fasting insulin levels  
such as HOMA-IR. Another limitation is the limited number of events in the longitudinal follow up,

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3 which was somehow expected. Therefore, additional studies in wider cohorts are needed to validate  
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5 our findings. An important issue is the lack of genetic data, particularly for *PNPLA3* variants that  
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7 have been extensively linked to more severe liver damage and increased risk of HCC. [48-49]  
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9 However, *PNPLA3* action is independent of IR both at the peripheral and hepatic levels, hence its  
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11 impact on the usefulness of insulin resistance/sensitivity indexes should be negligible.  
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15 In conclusion, this proof-of-principle study provides the rationale for the use of OGIS as non  
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17 invasive index of liver damage as well as predictor of metabolic complications in a low-risk  
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19 population of NAFLD subjects, and its effectiveness should be validated both cross-sectionally and  
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21 longitudinally in larger cohorts.  
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For Peer Review

## Figure Legends

**Fig. 1.** Correlation of Hepatic Insulin Resistance Index (HIRi) (A-C) and Glucose Clearance (D-F) as a Function of the best Surrogate Indexes in the Validation Group of NAFLD patients (black circles) and in Controls (open circles). The diagonal indicates the linear regression line.

Abbreviations: AUC, area under the receiver operating curve;  $eMCR^{nodem}$ , metabolic clearance rate estimation without metabolic parameters; HIRi, hepatic insulin resistance index; HOMA, homeostasis model assessment; IR, insulin resistance; ISI, insulin sensitivity index; OGIS, oral glucose insulin sensitivity index.

**Fig. 2.** Glucose and Insulin curves during OGTT according to the stage of fibrosis (A-B) or the degree of steatosis (C-D) in obese and non-obese subjects with NAFLD (Independent Cohort, n=145)

Abbreviations:  $F<2$ , absent/mild fibrosis;  $F\geq 2$ , moderate/severe fibrosis; Ob, obese; S1/S2, mild/moderate steatosis (< 66%); S2, severe steatosis ( $\geq 66\%$ ).

**Fig.3.** Oral Glucose Insulin Sensitivity Index (A) and NAFLD Fibrosis Score (B) according to the degree of fibrosis (Independent Cohort, n=145). The boxes identify the median and the 25<sup>th</sup> and 75<sup>th</sup> percentiles, while the whiskers stretch to the 5<sup>th</sup> and 95<sup>th</sup> percentiles.

Abbreviations: F0/F1, absent/mild fibrosis; F2, moderate fibrosis; F3/F4, severe fibrosis; NFS, non-alcoholic fatty liver disease fibrosis score; OGIS, oral glucose insulin sensitivity index.

**Fig. 4. Long-Term Outcomes Based on OGIS and NAFLD Fibrosis Score Risk Categories.**

The grey area is «high risk» according to the corresponding score (OGIS or NFS). Subjects have been divided according to the absence (no events) or development (events) of liver-related and metabolic complications. The horizontal lines represent the cut-offs.

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Abbreviations: NFS, non-alcoholic fatty liver disease fibrosis score; OGIS, oral glucose insulin sensitivity index.

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**Table 1.** Characteristics of the Patient Population in the Tracer Study Group (Validation Cohort) and in the Database Cohort (Independent Cohort).

Variable	Validation cohort (n = 22)	Independent cohort (n = 145)	P value
Age /years	42 ± 13	43 ± 10	ns
Gender (M), n (%)	20 (69)	117 (81)	ns
BMI (kg/m <sup>2</sup> )	28 ± 4	27 ± 5	ns
Normal weight/Overweight/Obese, %	18.2/54.5/27.3	22.8/57.9/19.3	ns
Waist (cm)	96 ± 11	96 ± 11	ns
AST (U/l)	39 (26)	33 (20)	ns
ALT (U/l)	78 (53)	72 (54)	ns
Albumin (g/dl)	4.5 (0.4)	4.5 (0.5)	ns
Platelets (x 10 <sup>9</sup> /l)	224 (71)	215 (75)	ns
Fasting insulin (mU/ml)	12 (4)	15 (17)	ns
Fasting glucose (mg/dl)	91 (13)	93 (16)	ns
Fasting triglycerides (mg/dl)	106 (73)	112 (81)	ns
Total cholesterol (mg/dl)	203 (39)	205 (64)	ns
HDL-cholesterol (mg/dl)	46 (18)	50 (16)	ns
Systolic pressure (mmHg)	123 ± 8.1	127 ± 16.4	ns
Diastolic pressure (mmHg)	78 ± 6.3	81 ± 8.5	ns
HOMA-IR	3.3 ± 1.9	3.8 ± 3.1	ns
<b>Histological features</b>			
Steatosis %	43 ± 26	36 ± 26	ns
Steatosis, n (%)			ns
1	10 (45.5)	80 (55.2)	
2	7 (31.8)	38 (26.2)	

	3	5 (22.7)	27 (18.6)	
Fibrosis, n (%)				ns
	0	7 (31.8)	51 (35.2)	
	1	1 (4.5)	22 (15.2)	
	2	6 (27.4)	35 (24.1)	
	3	7 (31.8)	29 (20.0)	
	4	1 (4.5)	8 (5.5)	
NAS score				ns
	0-2	2 (9.1)	24 (16.6)	
	3-4	12 (54.5)	92 (63.4)	
	5-6	8 (36.4)	29 (20.0)	
NASH, n (%)		20 (90.9)	88 (60.7)	0.0036

**Note.** Data are reported as mean  $\pm$  SD for continuous normal variables, median (interquartile range) for continuous non-normal variables and number (%) for categorical variables. BMI categories were defined as follow: normal weight (BMI 18.5-24.9 kg/m<sup>2</sup>), overweight (BMI 25-29.9 kg/m<sup>2</sup>), obese (BMI  $\geq$  30 kg/m<sup>2</sup>). ALT, alanine aminotransferases; AST, aspartate aminotransferases; BMI, body mass index; HDL, high density lipoprotein; IR, insulin resistance; HOMA, homeostasis model of assessment; M, male; NAS, non-alcoholic fatty liver disease activity score; NASH, non-alcoholic steatohepatitis.

**Table 2.** Parameters of Hepatic IR and Peripheral Insulin Sensitivity from Tracers Studies and Surrogate Indexes in the Validation Group of NAFLD Patients.

Variables	NAFLD (n = 22)	Controls (n = 11)	<i>P</i> value
Age, years	42.3 (2.9)	39.1 (2.5)	ns
Gender M/F, n	16/6	8/3	ns
BMI, kg/m <sup>2</sup>	27.4 (0.7)	26.2 (1.0)	ns
<b>Tracer study</b>			
EGP (μmol/min kg)	10.1 ± 1.51	8.81 ± 1.35	0.0145
HIRi (μmol/min kg*UI/mL)	140 ± 76	90 ± 25	0.0084
Glucose clearance (ml/min kg)	1.94 ± 0.64	2.41 ± 0.51	0.0391
<b>Based on fasting measurements</b>			
HOMA-IR	3.36 ± 1.94	2.37 ± 0.70	0.0491
QUICKI	0.327 ± 0.025	0.337 ± 0.014	ns
FIRI	54 ± 31	39 ± 11	ns
IGR	0.143 ± 0.069	0.111 ± 0.029	0.0267
ISI Bennett	0.086 ± 0.011	0.097 ± 0.011	0.0117
TG/HDL-C	2.75 ± 1.76	1.29 ± 0.35	0.0006
<b>Based on OGTT measurements</b>			
OGIS (mg/Kg min)	8.40 ± 2.18	10.03 ± 1.19	0.0282
ISI Matsuda	2.63 ± 1.09	4.03 ± 0.99	0.0013
SiOGTT	0.193 ± 0.012	0.203 ± 0.007	0.0177
ISI Stumvoll	0.055 ± 0.043	0.084 ± 0.016	0.0295
HepIR-DF	63 ± 21	41 ± 19	0.0082
LIRI	2.26 ± 0.15	2.12 ± 0.11	0.0117
BIGTT	3.98 ± 3.21	6.54 ± 2.43	0.0267
eMCR <sup>dem</sup>	5.14 ± 4.13	7.91 ± 1.62	0.0392

eMCR <sup>nodem</sup>	4.71 ± 3.90	7.37 ± 7.31	0.0295
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**Note.** Data are reported as mean ± SD.

BMI, body mass index; FIRI, fasting insulin resistance index; HepIR, hepatic insulin resistance index; BIGTT,  $\beta$ -cell function, insulin sensitivity, glucose tolerance test derived index; eMCR<sup>dem</sup>, metabolic clearance rate estimation including demographic parameters; eMCR<sup>nodem</sup>, metabolic clearance rate estimation without demographic parameters; HIRi, hepatic insulin resistance index; HOMA, homeostasis model of assessment; IGR, insulin to glucose ratio; IR, insulin resistance; ISI, insulin sensitivity index; LIRI, liver insulin resistance index; M, male; NAFLD, non-alcoholic fatty liver disease; OGIS, oral glucose insulin sensitivity index; OGTT, oral glucose tolerance test; QUICKI, quantitative insulin sensitivity check index; SiOGTT, insulin sensitivity index derived from oral glucose tolerance test; TG/HDL-C, triglycerides to HDL-cholesterol ratio.

**Table 3.** Univariate and Multivariate Analysis of Surrogate Indexes Associated with Moderate/Severe Fibrosis ( $F \geq 2$ ).

	Univariate analysis			Multivariate analysis		
	Fibrosis < 2 (n = 73)	Fibrosis $\geq$ 2 (n = 72)	P value	OR	95% CI	P value
Age	41.2 $\pm$ 9.2	46.0 $\pm$ 12.4	0.0109	-	-	ns
Sex, M/F	62/11	55/17	0.2746	-	-	ns
BMI	26.3 $\pm$ 3.5	28.3 $\pm$ 3.4	0.0021	-	-	ns
HOMA-IR	4.01 $\pm$ 3.5	4.85 $\pm$ 3.9	ns	-	-	-
QUICKI	0.33 $\pm$ 0.04	0.32 $\pm$ 0.04	ns	-	-	-
FIRI	65 $\pm$ 56	78 $\pm$ 64	ns	-	-	-
IGR	0.19 $\pm$ 0.14	1.19 $\pm$ 0.12	ns	-	-	-
ISI Bennett	0.099 $\pm$ 0.046	0.093 $\pm$ 0.06	ns	-	-	-
TG/HDL-C	2.6 $\pm$ 1.8	3.3 $\pm$ 2.4	ns	-	-	-
OGIS (mg/Kg min)	9.24 $\pm$ 1.70	7.79 $\pm$ 1.88	<0.0001	0.70	0.58-0.85	<b>0.0002</b>
ISI Matsuda	3.44 $\pm$ 2.40	2.64 $\pm$ 2.32	0.0091	-	-	ns
SiOGTT	0.196 $\pm$ 0.011	0.190 $\pm$ 0.01	0.0002	-	-	ns
ISI Stumvoll	0.067 $\pm$ 0.049	0.047 $\pm$ 0.049	0.0044	-	-	ns
HepIR DF	74 $\pm$ 54	87 $\pm$ 73	ns	-	-	-
LIRI	2.25 $\pm$ 0.15	2.30 $\pm$ 0.12	0.0180	-	-	ns
BIGTT	4.54 $\pm$ 3.30	2.90 $\pm$ 2.44	0.0020	-	-	ns
eMCR <sup>dem</sup>	6.89 $\pm$ 4.03	4.62 $\pm$ 3.34	<0.0001	-	-	ns
eMCR <sup>nodem</sup>	5.71 $\pm$ 4.25	3.90 $\pm$ 4.01	0.0005	-	-	ns

**Note.** Data are reported as mean  $\pm$  SD.

BMI, body mass index; CI, confidence interval; BIGTT,  $\beta$ -cell function, insulin sensitivity, glucose tolerance test derived index; eMCR<sup>dem</sup>, metabolic clearance rate estimation including demographic parameters; eMCR<sup>nodem</sup>, metabolic clearance rate estimation without demographic parameters; HDL-C, high density



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lipoprotein cholesterol; HOMA, homeostasis model of assessment; IGR, insulin to glucose ratio; IR, insulin resistance; ISI, insulin sensitivity index; LIRI, liver insulin resistance index; OGIS, oral glucose insulin sensitivity index; OR, odds ratio; QUICKI, quantitative insulin sensitivity check index; SiOGTT, insulin sensitivity index derived from oral glucose tolerance test; TG, triglycerides.

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**Table 4.** Univariate and Multivariate Analysis of Surrogate Indexes Associated with the Diagnosis of NASH.

	Univariate analysis			Multivariate analysis		
	SFL (n = 57)	NASH (n = 88)	P value	OR	95% CI	P value
Age	40.9 ± 9.8	45.4 ± 12.1	0.0193	-	-	ns
Sex, M/F	62/11	55/17	ns	-	-	ns
BMI	26.6 ± 3.7	27.8 ± 3.4	0.0471	-	-	ns
HOMA-IR	4.34 ± 3.78	4.49 ± 3.70	ns	-	-	-
QUICKI	0.33 ± 0.04	0.32 ± 0.04	ns	-	-	-
FIRI	70 ± 61	73 ± 60	ns	-	-	-
IGR	0.20 ± 0.15	0.18 ± 0.12	ns	-	-	-
ISI Bennett	0.097 ± 0.047	0.095 ± 0.06	ns	-	-	-
TG/HDL-C	2.7 ± 1.9	3.1 ± 2.3	ns	-	-	-
OGIS (mg/Kg min)	9.20 ± 2.04	8.08 ± 1.94	0.0012	0.75	0.63-0.90	<b>0.0021</b>
ISI Matsuda	3.29 ± 2.22	2.88 ± 2.48	ns	-	-	-
SiOGTT	0.196 ± 0.011	0.191 ± 0.01	0.0176	-	-	ns
ISI Stumvoll	0.065 ± 0.053	0.052 ± 0.048	ns	-	-	-
HepIR DF	78 ± 58	83 ± 68	ns	-	-	-
LIRI	2.26 ± 0.15	2.28 ± 0.13	ns	-	-	-
BIGTT	4.40 ± 3.30	3.29 ± 2.73	0.0491	-	-	ns
eMCR <sup>dem</sup>	6.81 ± 4.33	5.10 ± 3.40	0.0001	-	-	ns
eMCR <sup>nodem</sup>	5.50 ± 4.56	4.37 ± 3.94	0.0143	-	-	ns

**Note.** Data are reported as mean ± SD.

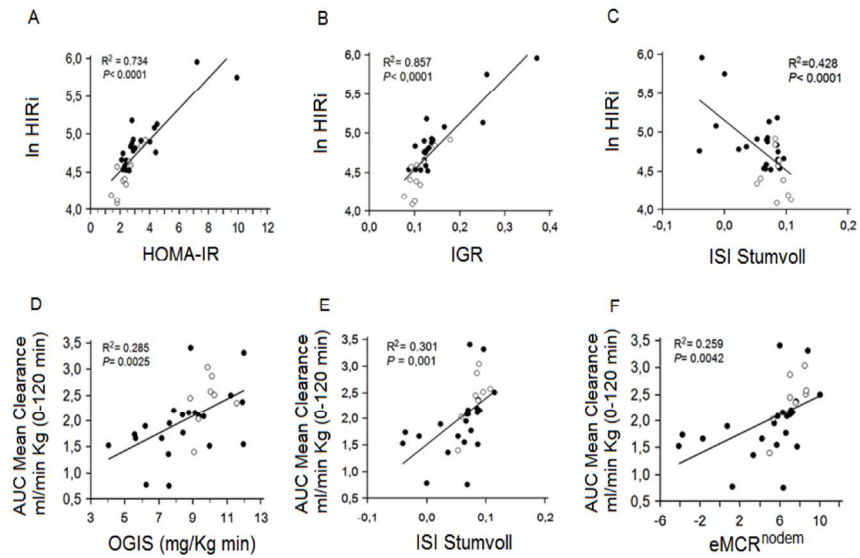
BMI, body mass index; CI, confidence interval; BIGTT,  $\beta$ -cell function, insulin sensitivity, glucose tolerance test derived index; eMCR<sup>dem</sup>, metabolic clearance rate estimation including demographic parameters; eMCR<sup>nodem</sup>, metabolic clearance rate estimation without demographic parameters; HDL-C, high

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density lipoprotein cholesterol; HOMA, homeostasis model of assessment; IGR, insulin to glucose ratio; IR, insulin resistance; ISI, insulin sensitivity index; LIRI, liver insulin resistance index; NASH, non-alcoholic steatohepatitis; OGIS, oral glucose insulin sensitivity index; OR, odds ratio; QUICKI, quantitative insulin sensitivity check index; SFL, simple fatty liver; SiOGTT, insulin sensitivity index derived from oral glucose tolerance test; TG, triglycerides.

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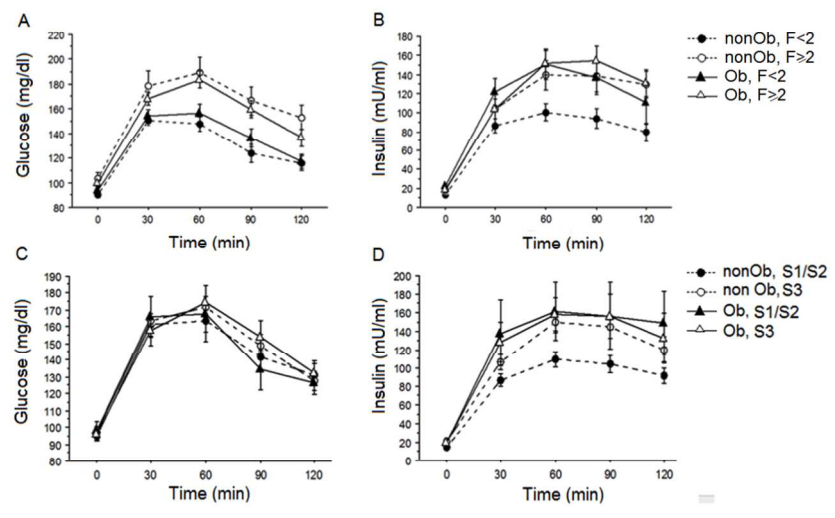
Fig. 1. Correlation of Hepatic Insulin Resistance Index (HIRi) (A-C) and Glucose Clearance (D-F) as a Function of the Best Surrogate Indices.



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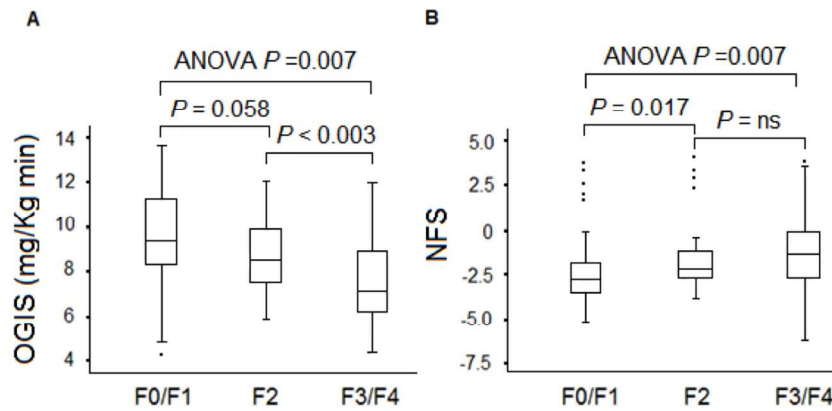
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Fig.2. Glucose and Insulin curves during OGTT according to the stage of fibrosis (A-B) or the degree of steatosis (C-D) in obese and non-obese subjects with NAFLD (Independent Cohort, n=145)



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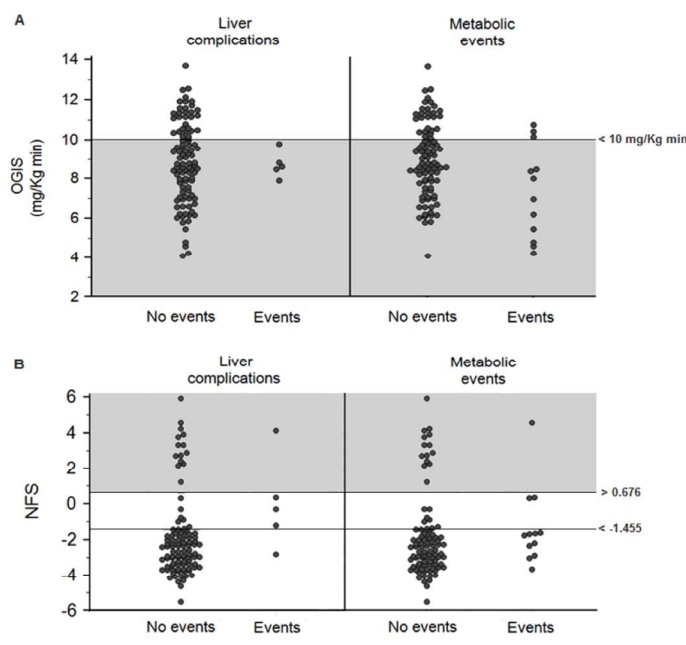
Fig.3. Oral Glucose Insulin Sensitivity Index (A) and NAFLD Fibrosis Score (B) according to the degree of fibrosis.



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Fig.4. Long-Term Outcomes Based on OGIS and NAFLD Fibrosis Score Risk Categories.



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## Supplementary Tables

## Supplementary table 1. Formulas of the Surrogate Indexes of Insulin Resistance/Insulin

Sensitivity.

	Formula
<b>Based on fasting measurements</b>	
HOMA-IR <sup>22</sup>	$(I_0 \text{ mU/ml} \times G_0 \text{ mmol/l}) / 22.5$
QUICKI <sup>23</sup>	$1 / (\text{LOG } I_0 \text{ mU/ml} + \text{LOG } G_0 \text{ mg/dl})$
FIRI <sup>24</sup>	$(I_0 \text{ mU/ml} \times G_0 \text{ mg/dl}) / 25$
IGR <sup>25</sup>	$I_0 \text{ mU/ml} / G_0 \text{ mg/dl}$
ISI Bennett <sup>26</sup>	$1 / (\ln G_0 \text{ mg/dl} \times \ln I_0 \text{ mU/l})$
TG/HDL-Chol <sup>38</sup>	Tg/HDL-Chol
<b>Based on OGTT measurements</b>	
OGIS <sup>27</sup>	$1/2 [B + \sqrt{B^2 + 4 p5p6(G120 - Gclamp)ClOGTT}]^S$
ISI Matsuda <sup>28</sup>	$10^4 / \sqrt{[(G_0 \text{ mg/dl} \times I_0 \text{ mU/ml}) \times (G_{\text{mean}} \times I_{\text{mean}})]}$
SiOGTT <sup>30</sup>	$1 / [\text{LOG}(G_0 + G_{30} + G_{90} + G_{120}) \text{ mg/dl} + \text{LOG}(I_0 + I_{30} + I_{90} + I_{120}) \text{ mU/ml}]$
ISI Stumvoll <sup>31</sup>	$0.157 - 0.00004576 \times I_{120} \text{ (pmol/l)} - 0.000299 \times I_0 \text{ (pmol/l)} - 0.00519 \times G_{120} \text{ (mmol/l)}$
HepIR DF <sup>32</sup>	$(G_0 \text{ mg/dl} + G_{30} \text{ mg/dl}) / 100 / 2 \times (I_0 \text{ mU/ml} + I_{30} \text{ mU/ml}) / 2$
LIRI <sup>33</sup>	$-0.091 + \text{LOG}(I_{\text{mean}} \times 6) \times 0.4 + \text{LOG}(FM / \text{weight} \times 100) \times 0.346 - \text{LOG HDL-C mg/dl}$ $\times 0.408 + \text{LOG BMI} \times 0.435$
BIGTT <sup>34</sup>	$\text{EXP}(4.9 - (0.00402 \times I_0 \text{ pmol/l}) - (0.000556 \times I_{30} \text{ pmol/l}) - (0.00127 \times I_{90} \text{ pmol/l}) - (0.152 \times G_0 \text{ mmol/l}) - (0.00871 \times G_{30} \text{ mmol/l}) - (0.0373 \times G_{120} \text{ mmol/l}) - (0.145 \times \text{Gender}) - (0.0376 \times \text{BMI}))$
eMCR <sup>dem 31</sup>	$18.8 - 0.271 \times \text{BMI} - 0.0052 \times I_{120} \text{ pmol/l} - 0.27 \times G_{90} \text{ mmol/l}$
eMCR <sup>nodem 31</sup>	$13 - 0.0042 \times I_{120} \text{ pmol/l} - 0.384 \times G_{90} \text{ mmol/l} - 0.0209 \times I_0 \text{ pmol/l}$



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3 ALB, albumin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; AUC, area under the  
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5 receiver operating curve; BIGTT,  $\beta$ -cell function, insulin sensitivity index derived from oral glucose  
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7 tolerance test; BMI, body mass index; eMCR<sup>dem</sup>, metabolic clearance rate estimation including demographic  
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9 parameters; eMCR<sup>nodem</sup>, metabolic clearance rate estimation without demographic parameters; FIRI, fasting  
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11 insulin resistance index; HDL-C, high density lipoprotein cholesterol; G, glucose; HepIR DF, De Fronzo  
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13 hepatic insulin resistance index; HOMA, homeostasis model of assessment; I, insulin; IFG, impaired fasting  
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15 glucose; IGR, insulin to glucose ratio; IR, insulin resistance; ISI, insulin sensitivity index; LIRI, liver insulin  
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17 resistance index; NFS, non-alcoholic fatty liver disease fibrosis score; OGIS, oral glucose insulin sensitivity  
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19 index; QUICKI, quantitative insulin sensitivity check index; SiOGTT, insulin sensitivity index derived from  
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21 oral glucose tolerance test; TG, triglycerides.  
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25 <sup>s</sup>p5 and p6 are fixed rate constants; G<sub>120</sub> is the plasma concentration of glucose measured at 120 min during  
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27 OGTT; GCLAMP is the clamp glucose concentration (normally 90 mg x dl<sup>-1</sup>); CIOGTT (the glucose  
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29 clearance during the test) and B are obtained by means of the following equations:  $B = [p_5 (G_{120} - G_{clamp}) + 1]$   
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**Supplementary Table 2.** Pearson Correlations of the Surrogate Indexes of Insulin

Resistance/Sensitivity as a Function of Glucose Clearance and Hepatic Insulin Resistance Index.

	<b>HIRi</b>	<b>Mean Clearance ml/min Kg (0-120 min)</b>
HOMA IR	0.901***	-0.451*
QUICKI	-0.783***	0.414*
FIRI	0.901***	-0.451*
IGR	0.926***	-0.148
ISI Bennett	-0.617**	0.304
TG/HDL-C	0.428	-0.409*
OGIS	-0.556**	0.531**
ISI Matsuda	-0.545**	0.399*
SiOGTT	-0.519	0.408*
ISI Stumvoll	-0.655***	0.548**
HepIR DF	0.374	0.082
LIRI	0.575**	-0.279
BIGTT	-0.572**	0.402*
eMCR <sup>dem</sup>	-0.564**	0.463**
eMCR <sup>nodem</sup>	-0.623**	0.507**

**Note.** BIGTT,  $\beta$ -cell function, insulin sensitivity, glucose tolerance test derived index; EGP, endogenous glucose production; eMCR<sup>dem</sup>, metabolic clearance rate estimation including demographic parameters; eMCR<sup>nodem</sup>, metabolic clearance rate estimation without demographic parameters; FPI, fasting plasma insulin; HDL-C, high density lipoprotein-cholesterol; HepIR, hepatic insulin resistance index; HOMA,

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3 homeostasis model of assessment; IGR, insulin to glucose ratio; IR, insulin resistance; ISI, insulin sensitivity  
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5 index; LIRI, liver insulin resistance index; NFS, non-alcoholic fatty liver disease fibrosis score; OGIS, oral  
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7 glucose insulin sensitivity index; QUICKI, quantitative insulin sensitivity check index; SiOGTT, insulin  
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9 sensitivity index derived from oral glucose tolerance test; TG, triglycerides.  
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11 \**P* value < 0.05

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3 **Supplementary table 3.** Area Under the ROC Curve of OGIS and NAFLD Fibrosis Score for the  
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5 Prediction of Advanced Fibrosis ( $F \geq 2$ ).  
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Index	Area under the ROC curve $\pm$ SE (95% CI)	PPV	NPV	<i>P</i> value
OGIS	0.71 $\pm$ 0.04 (0.62 - 0.78)	79	62	<0.0001
NFS	0.68 $\pm$ 0.04 (0.60 - 0.76)	63	74	<0.0001

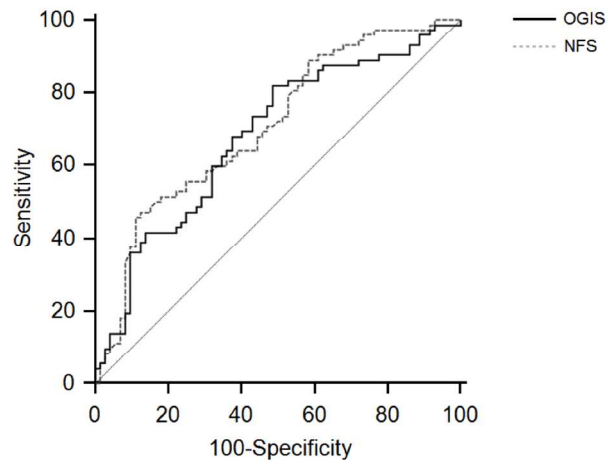
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19 CI, confidence interval; NFS, non-alcoholic fatty liver disease fibrosis score; NPV, negative predictive  
20 value; OGIS, oral glucose insulin sensitivity index; PPV, positive predictive value; ROC, receiver operating  
21 curve; SE, standard error.  
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**Supplementary table 4.** Comparison Between OGIS and NFS as Predictors of Advanced Fibrosis (F  $\geq$  2) by Logistic Regression Analysis.

	OR	95% CI	P value
Age	-	-	ns
Sex	-	-	ns
BMI	-	-	ns
OGIS (mg/Kg min)	0.69	0.57-0.84	<0.001
NFS	1.23	1.03-1.45	0.018

**Note.** BMI, body mass index; CI, confidence interval; NFS, non-alcoholic fatty liver disease fibrosis score; OGIS, oral glucose insulin sensitivity index; OR, odds ratio.

Supplementary Fig. 1. Receiver Operating Curve of the OGIS Index and NAFLD Fibrosis Score in the Prediction of Advanced Fibrosis ( $F \geq 2$ ).



supplementary figure  
508x381mm (72 x 72 DPI)