Obes Facts 2015;8:1–16
DOI: 10.1159/000373881

Table 2. Complete blood count of subjects

	Control group (n = 11)	Obese group (n = 12)
Erythrocytes × 10^4/μl	499 (420–566)	552 (473–635)*
Hb, g/dl	15.1 (11.5–17.1)	16.3 (13.8–17.8)
Ht, %	44.0 (34.5–48.7)	46.8 (40.7–51.2)
MCV, fl	89.7 (76.8–93.1)	85.5 (80.6–92.1)
MCH, pg	30.3 (25.6–33.0)	29.4 (27.7–32.5)
MCHC, %	34.5(32.1–36.5)	34.8 (33.8–36.2)
Total leukocytes/μl	5,060 (3,480–11,090)	7,120 (4,090–11,600)*
Neutrophils/μl	3,106 (2,168–7,995)	4649 (1,950–8,827)
Lymphocytes/μl	1,788 (890–2,439)	2,141 (1,587–3,161)
Monocytes/μl	298 (197–487)	419 (269–552)**
Eosinophils/μl	130 (32–391)	152 (37–209)
Basophils/μl	32 (19–44)	29 (8–42)
Plt × 10^4/μl	22.9 (17.2–32.4)	26.1 (20.2–34.7)

Hb = Hemoglobin; Ht = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin concentration; MCHC = mean cell hemoglobin concentration; Plt = platelets.

*$p < 0.05$, **$p < 0.01$ versus the control group.

Discussion

In this study, we analyzed 12 obese and 11 normal (control) young adults and demonstrated that i) peripheral total leukocyte and monocyte counts increased significantly in obese young adults, ii) total leukocyte count was associated with liver enzyme levels, insulin resistance, and visceral and subcutaneous fat thickness in young adults, iii) neutrophil count was associated with insulin resistance, iv) lymphocyte count was associated with serum liver enzymes, insulin resistance and dyslipidemia, and v) monocyte count was associated with serum liver enzyme, insulin resistance, visceral and subcutaneous fat thickness as well as body fat mass and percentage body fat.

Peripheral total leukocyte count was reportedly elevated in patients with NAFLD [20], and the presence of NAFLD was significantly associated with higher peripheral total leukocyte and monocyte counts [21]. In addition, a recent meta-analysis of 20 studies demonstrated a positive correlation between increased peripheral total leukocyte counts and diabetes risk [22]. Peripheral total leukocyte count is reportedly an independent risk factor for type 2 diabetes in young men at values well within the normal range, and overweight and obese subjects with relatively low peripheral total leukocyte counts seem to be at a significantly lower risk of diabetes compared with those with higher leukocyte counts [23]. Furthermore, peripheral total leukocyte count has also been associated with dyslipidemia [24, 25] and is suggested to be a predictor of coronary heart disease [26]. In the present study, peripheral total leukocyte and monocyte counts were significantly higher in obese young adults, and in an analysis of 23 subjects, we demonstrated that these counts were associated with serum liver enzyme, insulin resistance, and fat volume. Because of the high prevalence (9 out of 12 subjects) of NAFLD in the obese group, we concluded that excessive and ectopic fat deposition appears to cause early systemic inflammation, leading to the elevation of peripheral inflammatory cells such as monocytes. Therefore, obese young adults with elevated total leukocytes and monocytes may be considered for early preventive intervention.

Several reports demonstrated that obese adults and children have increased peripheral CD4+ T cells [8, 9, 12, 27, 28], but not CD8+ T cells [8, 9, 27]. These results suggest a selective

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881

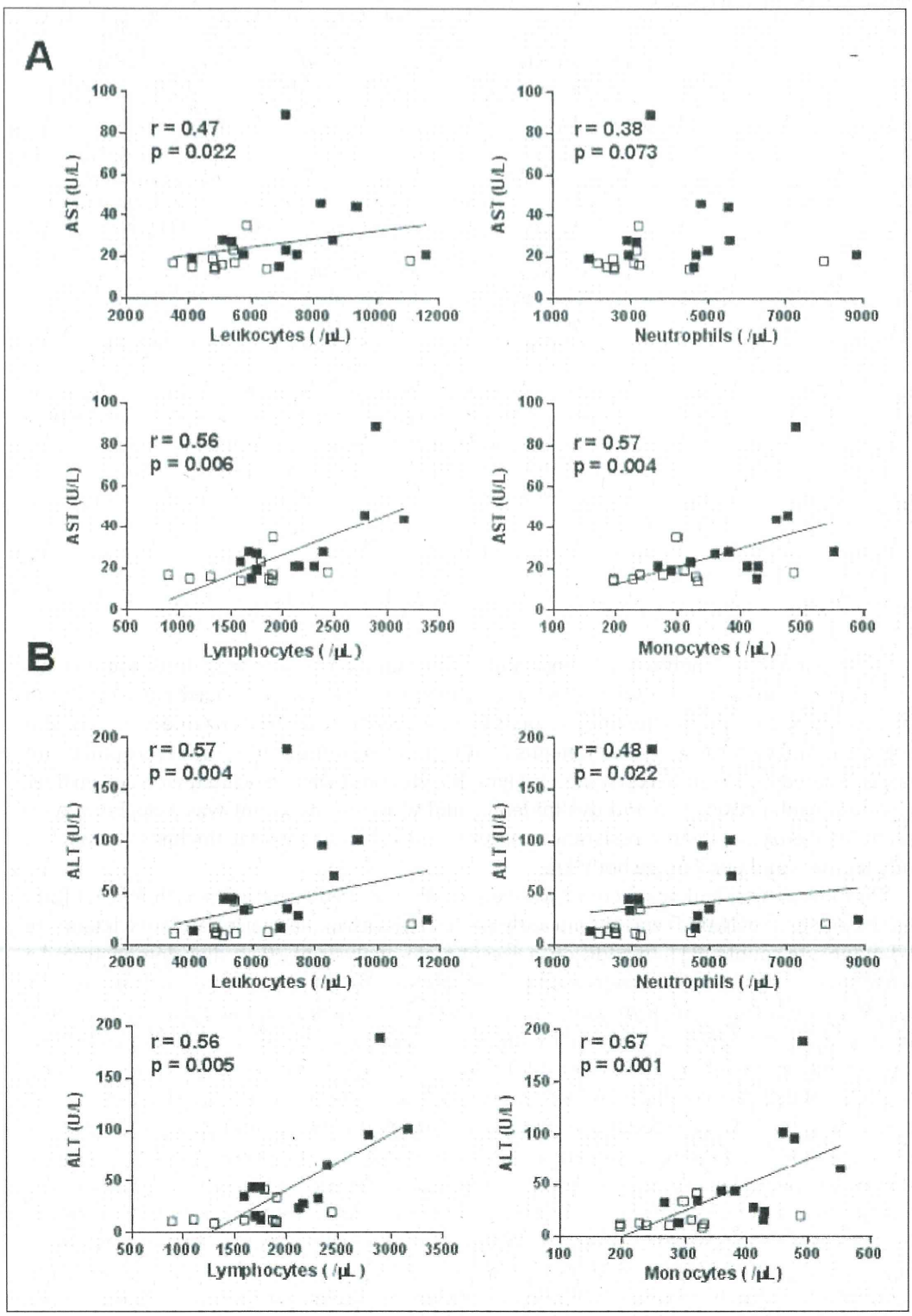
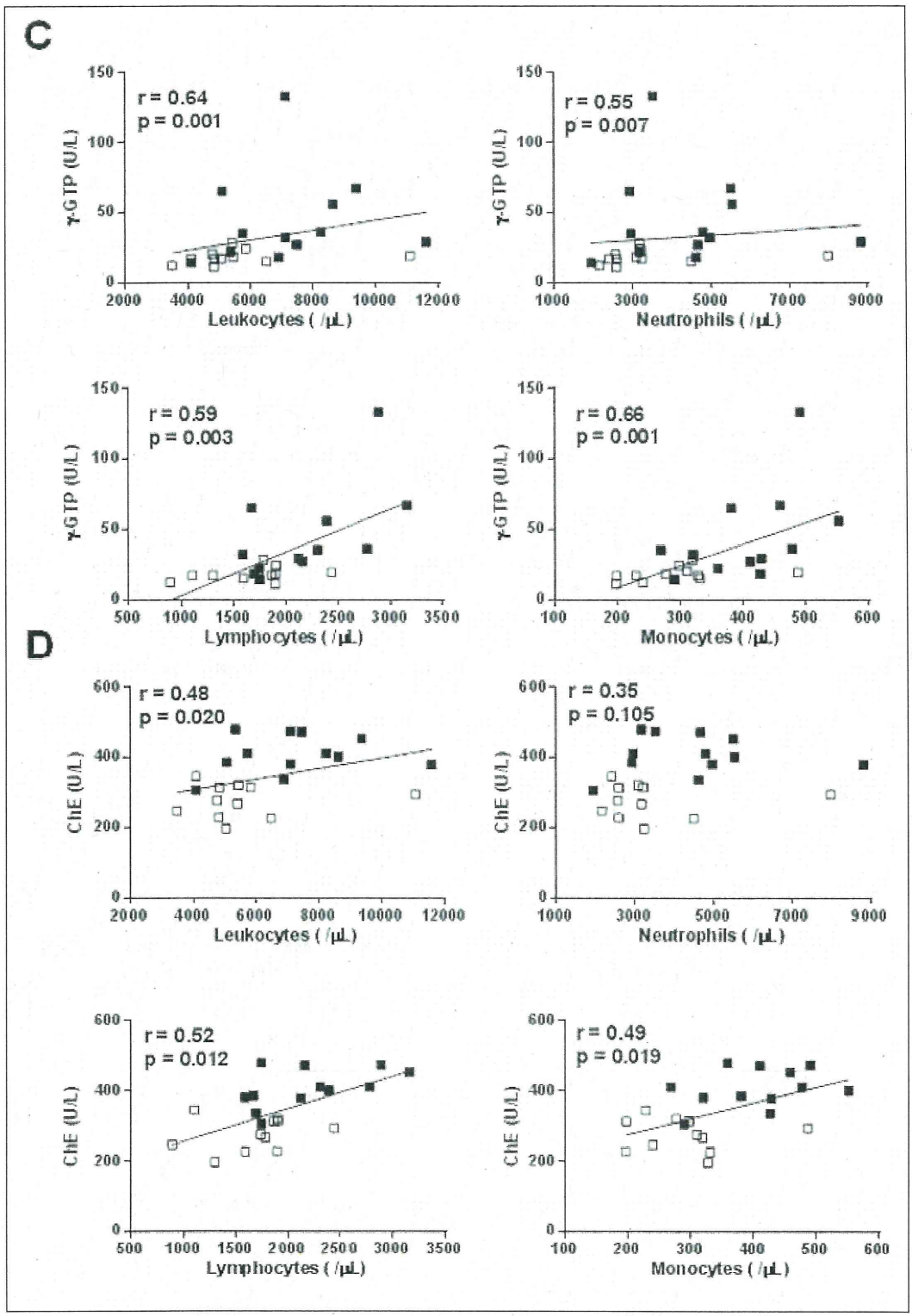


Fig. 1. Correlation of peripheral total leukocyte, neutrophil, lymphocyte and monocyte counts with serum levels of **A** aspartate aminotransferase (AST), **B** alanine aminotransferase (ALT), **C** γ-glutamyl transpeptidase (γ-GTP), and **D** choline esterase (ChE). Open squares represent control subjects. Closed squares represent obese subjects

(For figure C, D see next page.)

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881



1

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881

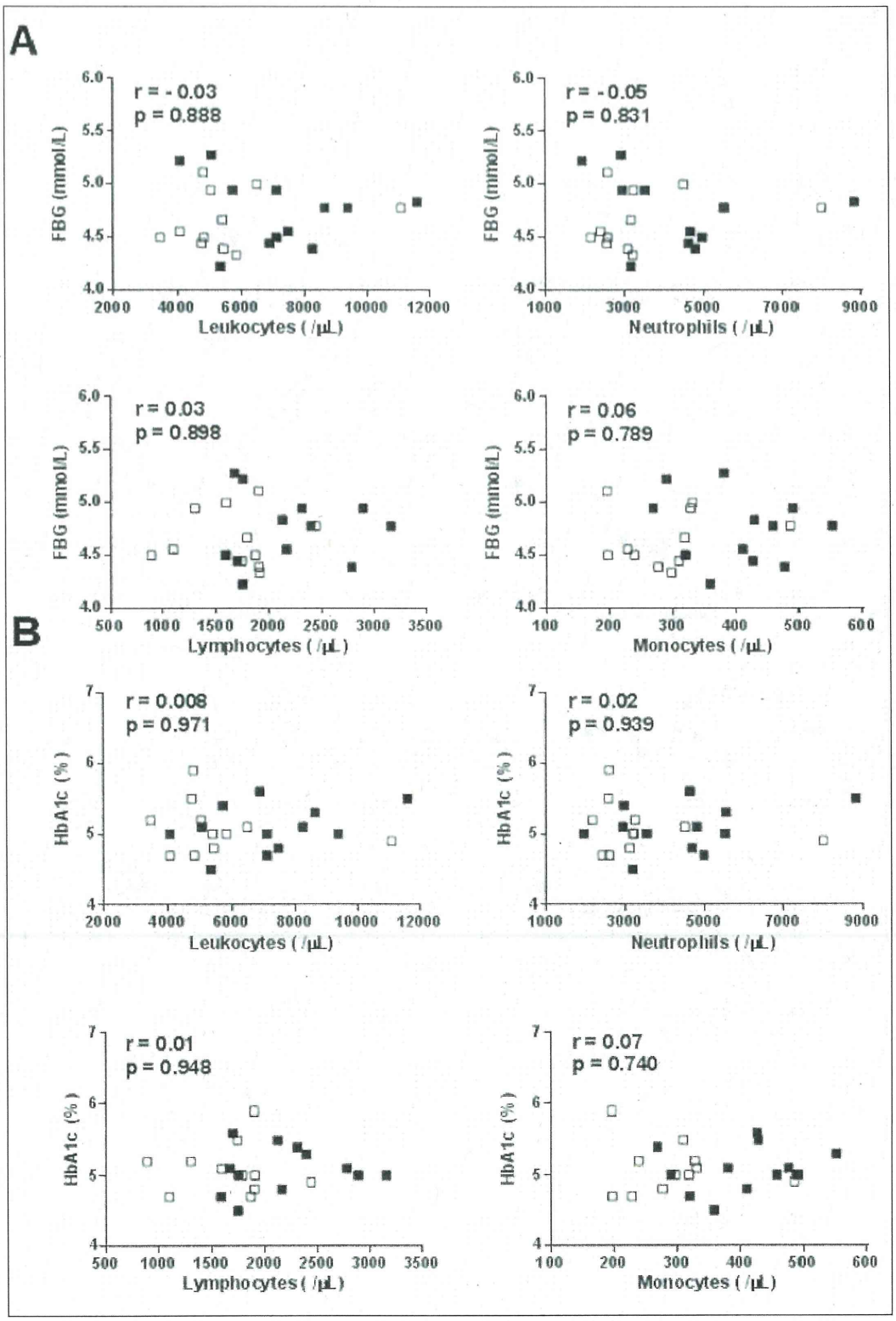
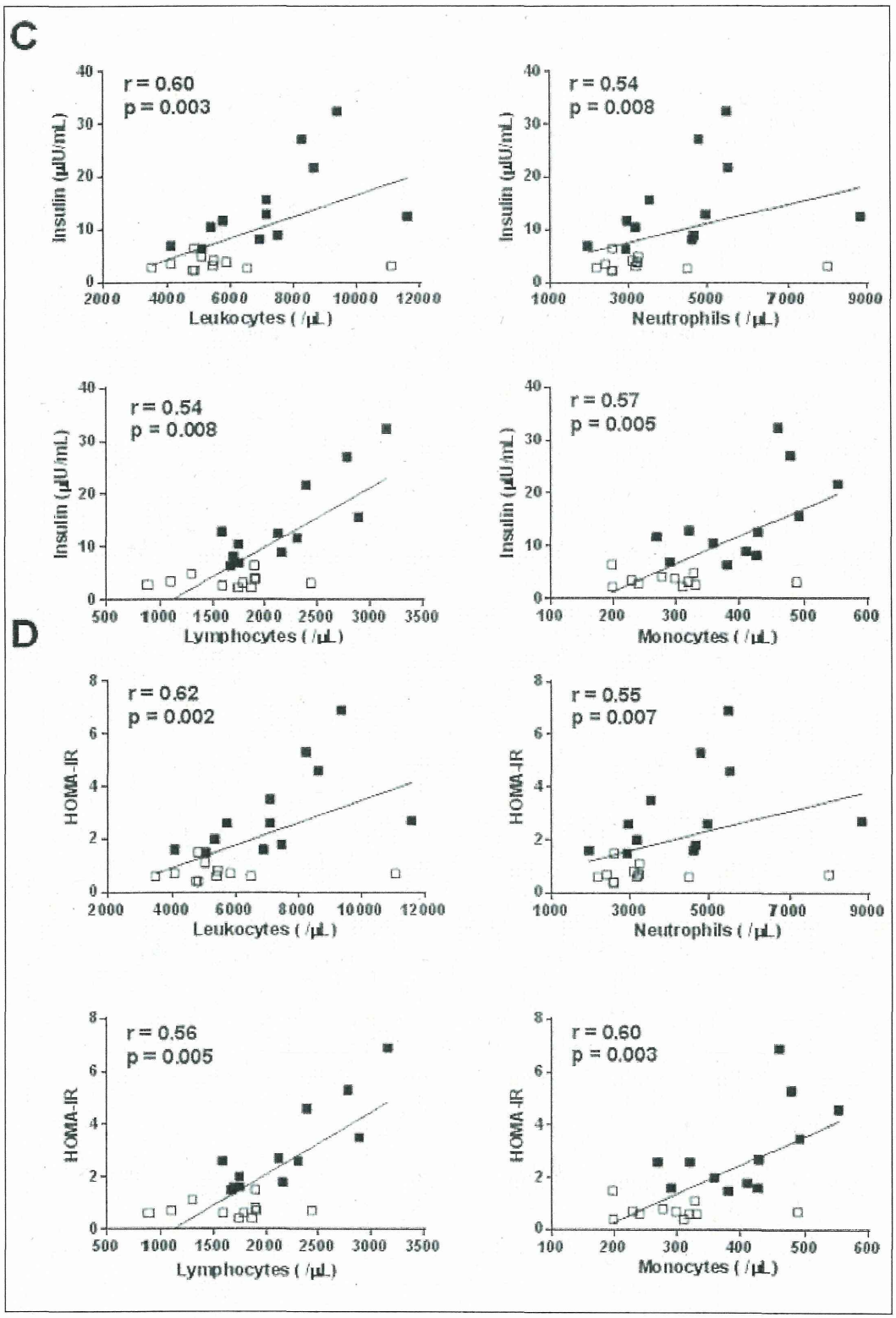


Fig. 2. Correlation of peripheral total leukocyte, neutrophil, lymphocyte and monocyte counts with **A** fasting blood glucose (FBG), **B** hemoglobin A1c (HbA1c), **C** insulin, and **D** homeostasis model assessment of insulin resistance (HOMA-IR). Open squares represent control subjects. Closed squares represent obese subjects.

(For figure C, D see next page.)

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881



2

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881

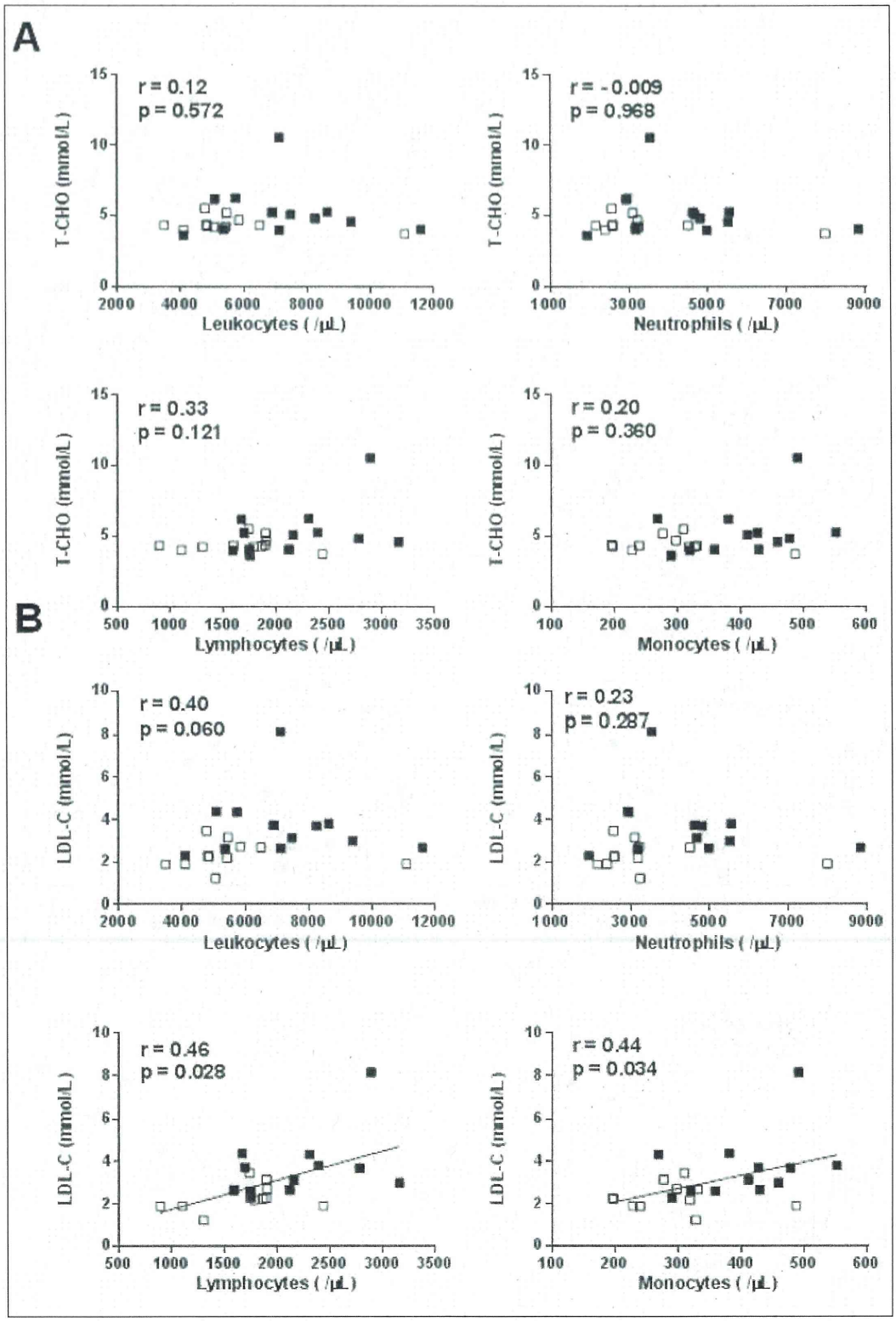
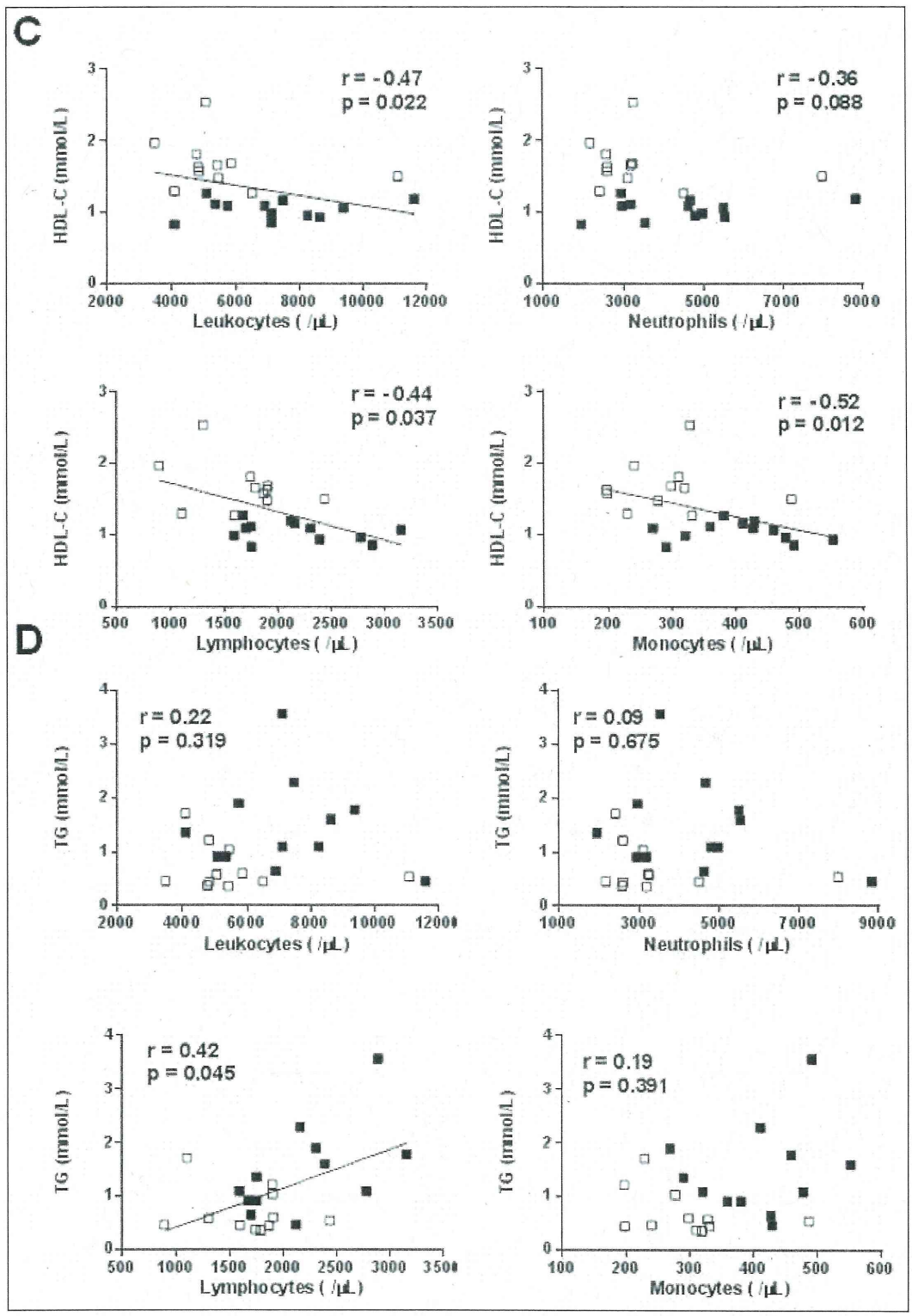


Fig. 3. Correlation of peripheral total leukocyte, neutrophil, lymphocyte and monocyte counts with **A** total cholesterol (T-CHO), **B** low-density lipoprotein cholesterol (LDL-C), **C** high-density lipoprotein cholesterol (HDL-C), and **D** triglycerides (TG). Open squares represent control subjects. Closed squares represent obese subjects.

(For figure C, D see next page.)

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881



3

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881

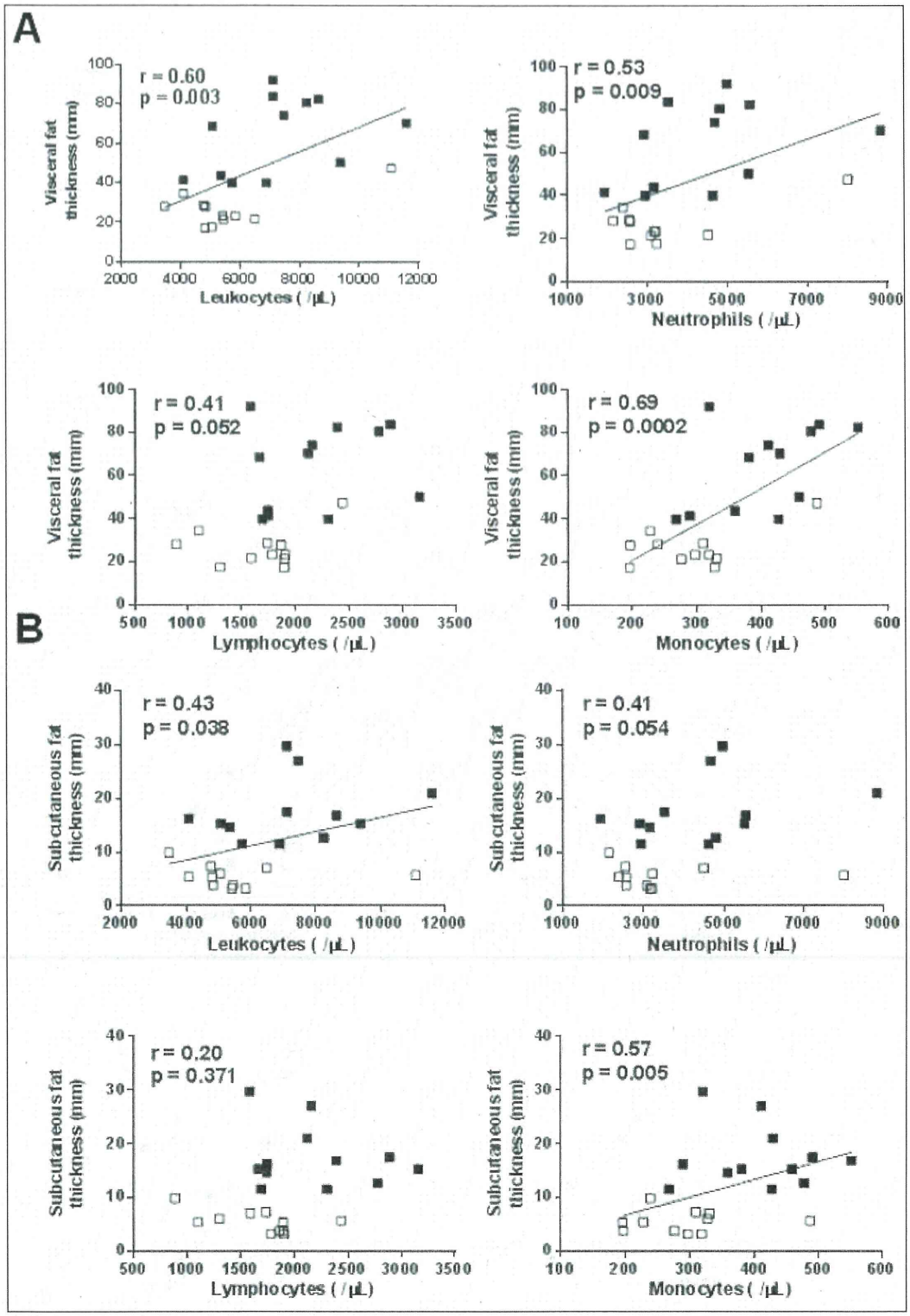
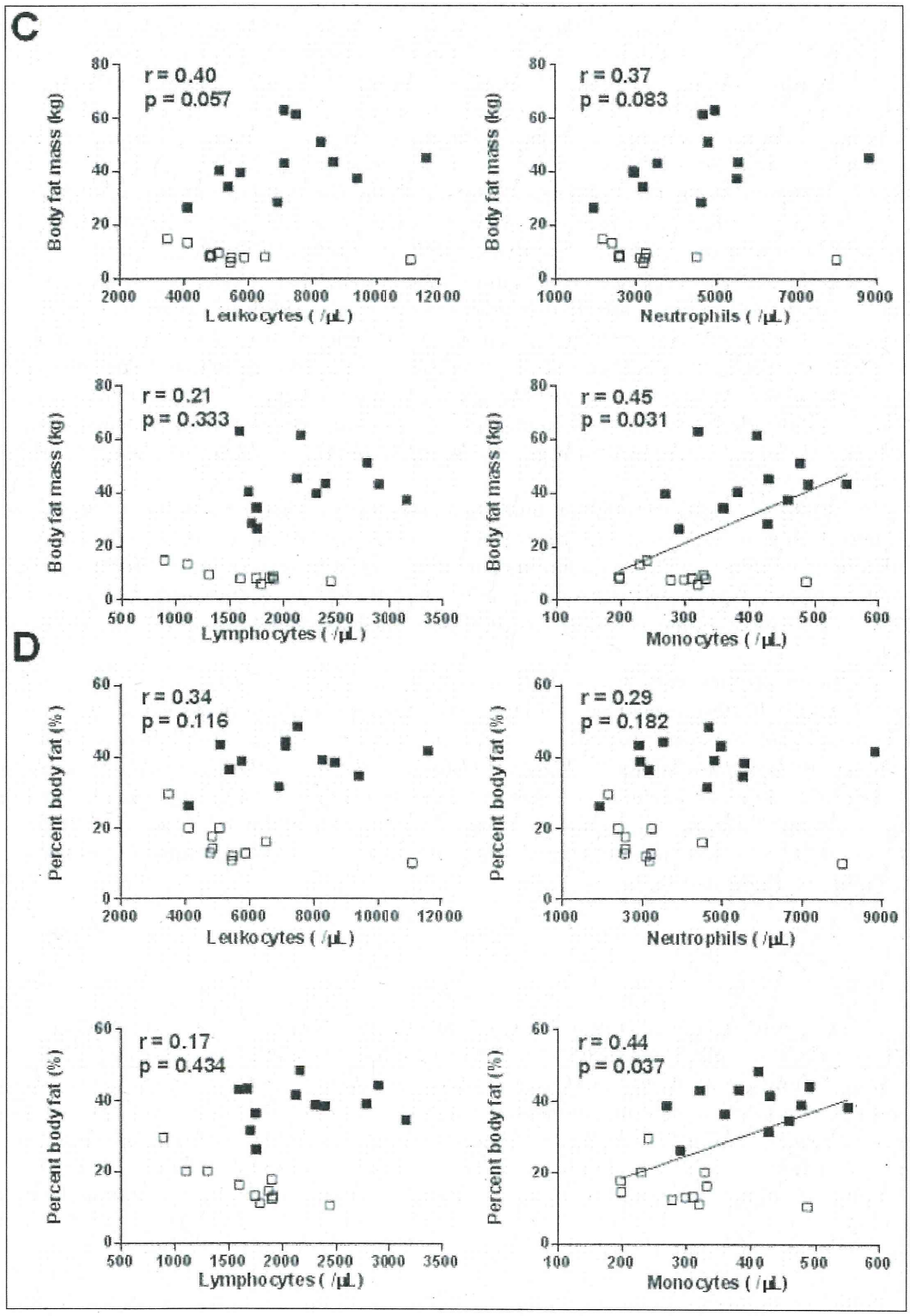


Fig. 4. Correlation of peripheral total leukocyte, neutrophil, lymphocyte and monocyte counts with **A** visceral fat thickness measured by ultrasonography, **B** subcutaneous fat thickness measured by ultrasonography, **C** body fat mass calculated by a bioimpedance analysis device, and **D** percentage body fat calculated by a bioimpedance analysis device. Open squares represent control subjects. Closed squares represent obese subjects.

(For figure C, D see next page.)

Obes Facts 2015;8:1–16
DOI: 10.1159/000373881



4

redistribution of CD8+ T cells into adipose tissue [29]. In addition, patients with nonalcoholic steatohepatitis (NASH) exhibited increased numbers of peripheral CD4+ T cells and both CD4+ CD45RO+ and CD8+ CD45RO+ memory T cells, together with a higher frequency of IFN-γ-producing CD4+ and CD8+ T cells [30]. Furthermore, greater numbers and activation of CD14+ monocytes were associated with hyperglycemia and increased atherosclerosis in obese adults and children [31–34]. It has also been reported that reactive oxygen species production is increased in the peripheral monocytes of obese patients [35]. Therefore, CD4+ T cells, memory T cells, or CD14+ monocytes may be the major subtypes of increased leukocytes, although we did not measure the surface markers of peripheral leukocytes.

The influence of subcutaneous fat is more modest than that of visceral fat; however, subcutaneous fat tissue also affects the inflammatory process [36]. In the present study, peripheral monocyte count positively correlated with visceral and subcutaneous fat thickness as well as with body fat mass and percentage body fat. These results suggest that the peripheral monocyte number reflects fat volume. Because the number of subjects was limited, it was difficult to conclude that lymphocyte count was not associated with visceral or subcutaneous fat thickness. Further studies with a larger number of subjects are required to investigate this in greater depth.

In the present study, erythrocyte count was significantly higher in the obese group than in the control group. Other studies reported that higher erythrocyte count was associated with pre-diabetes, obesity, metabolic syndrome, and insulin resistance [37–39]. The activation of tyrosine kinase in the insulin receptor, which could be essential for the growth-promoting action of insulin, is widely accepted as the mechanism accounting for this finding [40].

Our study demonstrated that serum amylase levels were significantly decreased in the obese group. It has been reported that low serum amylase levels were associated with an increased risk of metabolic abnormalities, metabolic syndrome, and diabetes [41] and with NAFLD in asymptomatic adults [42]. An explanation for this relationship is systemic ectopic fat deposition in organs, including the pancreas, and studies have linked intrapancreatic fat deposition with NAFLD and metabolic syndrome [43, 44]. Systemic fat deposition in multiple organs may therefore be a common cause for NAFLD and pancreatic dysfunction, causing impaired exocrine function.

Conclusions

In conclusion, peripheral total leukocyte and monocyte counts are associated with obesity-related complications such as NAFLD, insulin resistance, and dyslipidemia in young adults; in addition, peripheral monocyte count is associated with fat volume. Given that chronic low-grade systemic inflammation contributes to morbidity and mortality, early detection of obesity in young adults and appropriate preventive intervention appear to be important. However, one limitation of the present study is the small number of subjects. Further studies with a larger number of participants will be required to corroborate our findings.

Acknowledgments

This work was supported in part by the Creation of Innovation Centers for Advanced Interdisciplinary Research Areas Program of the Ministry of Education, Culture, Sports, Science and Technology, Japan. We thank Koji Oba for statistical analysis, and the participating students for their co-operation.