1521-009X/41/4/689–693$25.00
DRUG METABOLISM AND DISPOSITION

http://dx.doi.org/10.1124/dmd.112.048884
Drug Metab Dispos 41:689–693, April 2013

Short Communication

Interleukins-12 and -23 Do Not Alter Expression or Activity of Multiple Cytochrome P450 Enzymes in Cryopreserved Human Hepatocytes[S]

Received September 7, 2012; accepted January 24, 2013

ABSTRACT

Psoriasis is a T-cell-mediated autoimmune disease involving the skin. Two cytokines, interleukin-12 (IL-12) and IL-23 have been shown to play a pivotal role in the pathogenesis of the disease. Ustekinumab (Stelara) is a therapeutic monoclonal antibody (mAb) targeted against the p40 shared subunit of IL-12 and IL-23. Recently the ability of therapeutic proteins (TP) including mAbs that target either cytokines directly (e.g., Pegasys; peginterferon α-2a) or their respective cell surface receptors [e.g., tocilizumab (Actemra); anti IL-6R] to desuppress cytochrome P450 (P450) enzymes in vitro and in the clinic, has been demonstrated. In the present study the ability of IL-12 and IL-23 to suppress multiple P450 enzymes was investigated in vitro using six separate lots of cultured human hepatocytes. Following exposure of 10 ng/ml IL-12 and IL-23 for 48 hours, either alone or in combination, no change in CYP2B6, 2C9, 2C19, or 3A4 gene expression or functional activity was observed. None of the untreated hepatocyte donors showed appreciable expression of the IL-12 or IL-23 receptors. Similar results were seen with whole human liver samples. Exposure of hepatocytes to IL-12 and/or IL-23, known P450 suppressors (IL-6 and tumor necrosis factor-α) or known P450 inducers (β-naphthoflavone, phenobarbital, and rifampicin) did not appreciably alter the expression of the IL-12 and IL-23 receptors either. Finally, in contrast to the positive control IL-6, expression of the acute phase C-reactive protein was unaltered following IL-12 and/or IL-23 treatment. Together, these data suggest a negligible propensity for IL-12 or IL-23 to directly alter P450 enzymes in human hepatocytes.

Introduction

The ability of therapeutic proteins (TP) that target cytokines to potentially mediate drug interactions through alterations in drug metabolizing enzymes is a growing concern in drug development (Huang et al., 2010). Patients with inflammatory disease often have increased circulating or local cytokine levels including interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and interferon-gamma, which have all been shown to alter cytochrome P450 (P450) metabolic enzyme levels in the liver (Morgan, 2009). The TP treatment that neutralizes one or more of these cytokines could result in patients experiencing rebound metabolic enzyme levels, leading to decreased comedication exposure and potentially therapeutic failure. As an example, recent clinical studies by Schmitt et al., (2011) showed significantly decreased simvastatin (Zocor) exposure in rheumatoid arthritis patients receiving tocilizumab, an anti-human IL-6 receptor mAb. The decreased exposure was linked to changes in CYP3A4 expression reported by the same group following anti-IL-6R treatment in the presence and absence of tocilizumab in cultured human hepatocytes (Zhang et al., 2009).

Psoriasis is a chronic inflammatory skin disease affecting approximately 2% of the population (Christophers, 2001; Nestle et al., 2009). Pathogenesis of psoriasis involves a complex interplay of various cytokines, including interferons-α and -γ, TNF-α, IL-1β, IL-6, IL-12, and IL-23, as well as chemokines CXCL8 through 11, CCL19 and CCL19-20 (Nestle et al., 2009). IL-12 and IL-23 have been shown to play a key role in the initiation as well as the maintenance of the disease state (Torti and Feldman, 2007; Nestle et al., 2009). Both IL-12 and IL-23 belong to the IL-12 family of cytokines, which in turn share homology with the IL-6 family and share common structural subunits as well as receptors (Gee et al., 2009). IL-12 is composed of p35 and p40 subunits, and the IL-12 receptor has two chains: IL-12Rβ1 and IL-12Rβ2. IL-23 is composed of p19 and p40 subunits, and the IL-23 receptor also has two chains: IL-12Rβ1 in combination with IL-23R. Ustekinumab (Stelara), a monoclonal antibody developed by Janssen Pharmaceuticals and approved by the FDA in 2010 for the treatment of moderate to severe plaque psoriasis, binds to the shared p40 subunit of IL-12 and IL-23 (Benson et al., 2011), thereby neutralizing the cytokines' bioactivity and subsequent molecular signaling pathways (Luo et al., 2010). However the impact of decreasing free circulating IL-12 and IL-23 levels on drug metabolizing enzymes is currently unknown. Because the IL-12 and IL-23 cytokines and their receptor subunits share homology with IL-6 and its receptor subunit gp130, respectively (Gee et al., 2009), we investigated the ability of IL-12 and/or IL-23 to modulate the expression and function of the major P450 enzymes. An in vitro model using cultured human hepatocytes was used for the study, and known modulators of the P450s (suppressors or inducers) were included as positive controls. The ability of IL-12 and IL-23 to alter the expression of IL-12 and IL-23 receptors, as well as an acute phase response marker C-reactive protein (CRP) was also examined.

dx.doi.org/10.1124/dmd.112.048884.
[S]This article has supplemental material available at dmd.aspetjournals.org.

ABBREVIATIONS: CRP, C-reactive protein; IL, interleukin; mAb, monoclonal antibody; P450, cytochrome P450; RT-PCR, reverse transcriptase-polymerase chain reaction; TNF-α, tumor necrosis factor-α; TP, therapeutic proteins.

In addition, the potential role of inflammatory cytokines in modulating the expression of the IL-12 and IL-23 receptor subunits was also determined.

Materials and Methods

Materials. Hepatocyte thawing and plating media were obtained from In Vitro Technologies (Baltimore, MD). All other tissue culture reagents were purchased from Invitrogen (Carlsbad, CA), unless otherwise stated. IL-6, IL-12, and IL-23 were purchased from R&D Systems (Minneapolis, MN). Hydroxybupropion, hydroxybupropion-d_6, S-(+)-mephenytoin, and 6β-hydroxytestosterone-d_7 were purchased from BD Biosciences (Woburn, MA). (+/−)-4-Hydroxymephenytoin, hydroxytolbutamide, and 6β-hydroxytestosterone were obtained from Ultrafine (part of BD Biosciences). Hydroxytolbutamide-d_9 and hydroxymephenytoin-d_3 were purchased from Synfine (Richmond Hill, ON, Canada). All other chemicals were purchased from Sigma-Aldrich (St. Louis, MO). Human peripheral blood mononuclear cells and human liver mRNA samples were purchased from commercial suppliers (Supplemental Table 1).

Human Hepatocyte Incubations. Six separate lots of cryopreserved human hepatocytes were purchased from commercial suppliers (donor characteristics are listed in Supplemental Table 1). Cell lots were chosen by first verifying the ability of the donors to regulate P450s generally by measuring P450 induction following incubations with well characterized nuclear receptor activators, i.e., an assay integrity test, as described previously (Dallas et al., 2012). Cells were thawed, prepared, and incubated according to Dallas et al. (2012). Briefly, at 48 hours postseeding the cells were dosed with freshly spiked William's E media containing 10 ng/ml IL-6, IL-12, IL-23, or IL-12+23 in combination. All cytokines were reconstituted according to the manufacturer's instructions to yield 10 mg/ml stock solutions and stored in single-use aliquots at −80°C. Negative controls were incubated with appropriate vehicle (0.1% dimethylsulfoxide for positive control inducers and 0.0001% human serum albumin for cytokines). Incubations were continued for 48 hours with fresh dosing of spiked media performed after 24 hours, at which time media were removed and appropriate probe substrates were added. P450 specific substrates were prepared as 500× stock solutions in dimethylsulfoxide (100 mM for bupropion, tolbutamide, S-mephenytoin, and testosterone). At the end of the incubation period, the corresponding P450-catalyzed postincubation samples were pooled and samples were analyzed by liquid chromatography-tandem mass spectrometry.

Liquid Chromatography-Mass Spectrometry Assay. The effect of the various cytokines on the activity of the P450 isoforms screened was determined by monitoring formation of the metabolite of each P450-specific probe substrate in the absence and presence of the cytokines as previously described (Dallas et al., 2012). A 12-point standard curve and five quality control levels in triplicate were prepared by spiking blank Kreb's Henseleit buffer with a serially diluted mixture of metabolite reference standards in methanol and included in the analytical plate with the pooled postincubation samples. Internal standards (as a mixture of the deuterated analogs of hydroxybupropion, hydroxytolbutamide, 4-hydroxymephenytoin, and 6β-hydroxytestosterone in methanol) were added, and the samples were then evaporated to dryness under a steady stream of filtered nitrogen gas and subsequently reconstituted in mobile phase (1:1 methanol: water, 0.1% acetic acid).

Samples were analyzed by liquid chromatography-triple quadrupole mass spectrometry on a Shimadzu binary 10AD-vp liquid chromatography pump system (Shimadzu Scientific Instruments, Columbia, MD) and a Leap CTC PAL autosampler (Leap Technologies, Carrboro, NC) coupled to a Sciex API 4000 triple quadrupole mass spectrometer operated in the Multiple Reaction Monitoring scan mode using electrospray ionization. Chromatographic separation of the probe substrate metabolites was achieved using a Betasil Phenyl Hexyl column (100 × 2.1 mm i.d., 3 μm) (Thermo Fisher Scientific, Inc., Bellefonte, PA), thermostatted at 50°C, with a binary mobile phase system consisting of 0.1% acetic acid (solvent A) and methanol containing 0.1% acetic acid (solvent B) at a flow rate of 0.5 ml/min. Data were acquired and reduced in Analyst 1.5.1 (AB Sciex, Concord, ON, Canada) and, after weighted (1/x) linear regression analysis (coefficient of determination, R^2, > 0.99), the standard curves were used to calculate the metabolic rates of formation. The potential for each of the cytokines to cause changes in P450 activity was determined as % control activity, i.e., (test rate/blank rate) ×100.

Cytotoxicity Assay. Cytotoxicity of the various treatments was assessed by visual inspection during the culture process and after experimentation, as well as by using an in vitro lactic dehydrogenase toxicology assay kit (TOX-7; Sigma-Aldrich) as described previously (Dallas et al., 2012). None of the cytokines used in the present study showed appreciable cytotoxicity at 10 ng/ml.

Reverse Transcription-Polymerase Chain Reaction Analysis. Total RNA was prepared using a Qiagen RNeasy 96 kit (Valencia, CA), and analysis of specific mRNA expression in total RNA samples was performed by real-time quantitative reverse transcription-polymerase chain (RT-PCR) reaction using TaqMan One-Step RT-PCR Master Mix Reagents kit and an Applied Biosystems ABI Prism 7900HT Sequence Detection system. All Taqman reagents including primer/probe sets (Supplemental Table 2) were purchased from Applied Biosystems (Foster City, CA). Real-time RT-PCR conditions were 1 cycle at 50°C for 2 minutes, 1 cycle at 95°C for 10 minutes, and 40 cycles at 94°C for 15 seconds and 56°C for 30 seconds. A comparative $\Delta\Delta C_T$ method was used for relative quantification of gene expression (Livak and Schmittgen, 2001; Kurebayashi et al., 2010), using 18S mRNA expression as an internal control. The fold expression, as reported, was calibrated to the vehicle control. If threshold cycle values were undetermined even after 40 cycles of PCR, expressions of the genes in those samples were considered beyond the limit of detection. Data analysis and statistical tests were performed using Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA).

Data Analysis. Functional activity and mRNA expression data are presented as mean ± S.E. from six different human donor lots. Statistical analysis was carried out using analysis of variance and a Bonferroni multiple comparison post hoc test. A value of $P < 0.05$ was considered statistically significant.

Results and Discussion

Pro-inflammatory cytokines like IL-6 and TNF-α have been shown to significantly suppress multiple P450 enzymes in human hepatocytes (mRNA and/or activity) (Aitken et al., 2006; Dickmann et al., 2011). In a recent publication from our laboratory, we have further confirmed these findings. Following 10 ng/ml IL-6 treatment, enzyme activity and mRNA levels of six different P450 enzymes (CYP1A2, 2B6, 2C9, 2C19, 2D6, and 3A4) were significantly decreased by 22–98% (Dallas et al., 2012). However, greater than 50% suppression was observed only for CYP2C19 and 3A4 (activity and mRNA) and CYP2B6 and 2C9 (mRNA only). Similar to our previous study, 10 ng/ml IL-6 suppressed the activity and/or mRNA expression of these four P450s significantly in the present studies, i.e., by >45%. In contrast, treatment of the hepatocytes using 10 ng/ml IL-12 and -23, either individually or in combination, did not result in any significant suppression of CYP2B6, 2C9, 2C19, or 3A4 activity (Fig. 1) or mRNA expression levels (Fig. 2). Functional activity of the IL-12 and IL-23 cytokines was verified by measuring IL-17 and interferon-γ secretion (Supplemental Table 3) following treatment of activated peripheral blood mononuclear cells (Oppmann et al., 2000; Reddy et al., 2007).

Markers of the acute phase response such as CRP are elevated in patients with psoriasis, but can be reduced upon treatment with anti-TNF-α or IL-6 therapies (Kanelleas et al., 2011; Schmitt et al., 2011). In cultured human hepatocytes, CRP levels increase significantly following IL-6 exposure (Dickmann et al., 2011). The p35 and the p40 subunits of the IL-12 and IL-23 cytokines are homologous to IL-6 and the IL-6Rα, respectively (Gee et al., 2009). Because the IL-12Rβ1 and IL-12Rβ2 receptor subunits are homologous to the gp130 receptor subunit of the IL-6 family (Gee et al., 2009), the effect of IL-12 and IL-23 on hepatocyte CRP levels (indicating a potential inflammatory reaction) was also evaluated. As expected, following exposure to 10 ng/ml IL-6, CRP levels rose in all six hepatocyte donors by 491 ± 30 fold versus the vehicle control, which is consistent with previous studies in cultured human hepatocytes (Dickmann et al., 2011). However no change in CRP levels was observed following incubation

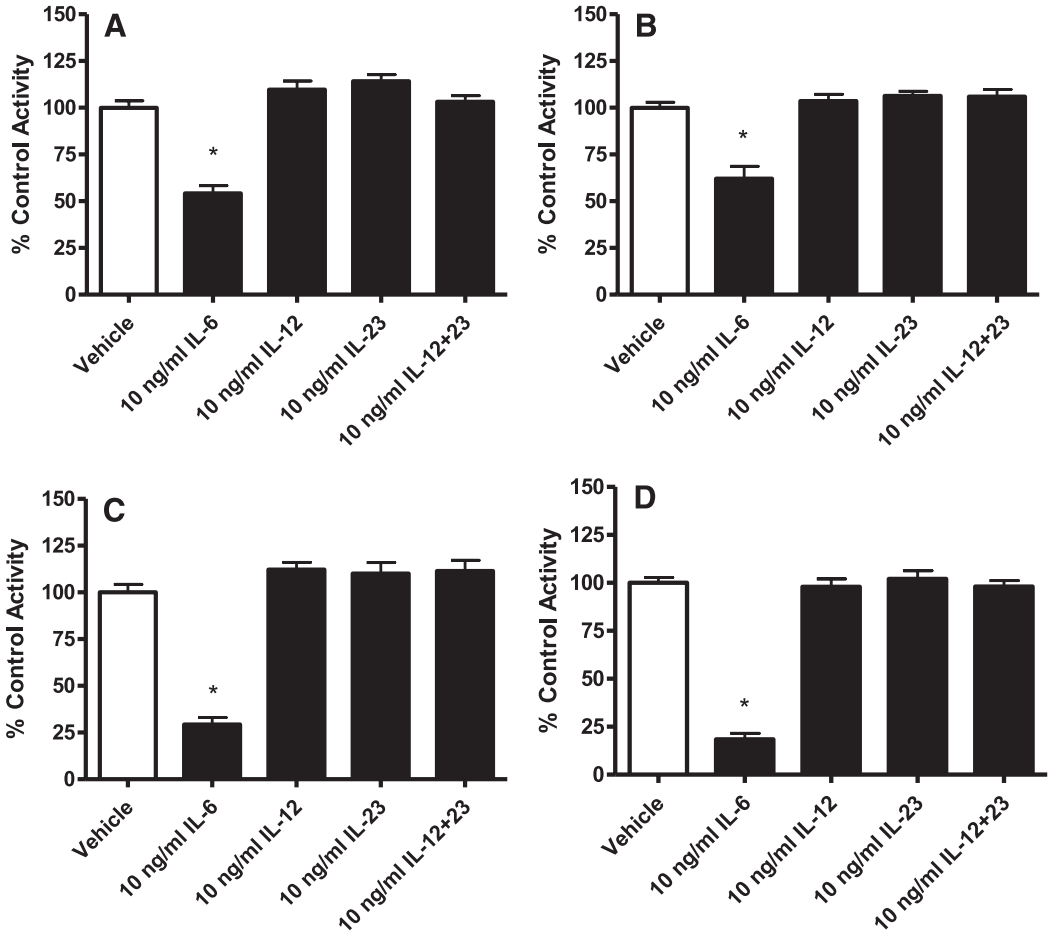

Fig. 1. Effect of IL-12 and/or IL-23 on enzyme activity of CYP2B6 (A), CYP2C9 (B), CYP2C19 (C), and CYP3A4 (D) in cryopreserved human hepatocytes. Six separate lots of cryopreserved human hepatocytes were incubated with 10 ng/ml IL-6, IL-12, IL-23, or IL-12+23 for 48 hours. At the conclusion of the incubation period, enzyme activity was assessed by monitoring metabolism of P450 specific substrates by LC-MS/MS as detailed in *Methods and Materials*. Data points are expressed as mean ± S.E. of experiments performed in six different hepatocyte donors. $*P < 0.05$ was considered statistically significant.

with IL-12 or IL-23, either alone or in combination (Fig. 3), indicating their inability to initiate an acute phase response in cultured human hepatocytes.

To further investigate the lack of response of human hepatocytes to IL-12 and IL-23, we assessed the mRNA expression of the IL-12 and IL-23 related receptors using quantitative RT-PCR. Nine replicates of each hepatocyte donor were assayed for each receptor (IL-12Rβ1, IL-12Rβ2, and IL-23R) in the presence or absence of IL-12 and IL-23 (individually and in combination). In the untreated control samples, the mRNA levels of all three receptors were below the detection limit of the assay, indicating insignificant expression in cultured human hepatocytes. The IL-23 expression data are consistent with recent observations by R. Evers from Merck and Co. (unpublished observations), who observed negligible expression of IL-23R in cultured human hepatocytes. Lack of significant IL-12Rβ1 and IL-12Rβ2 expression was also demonstrated previously in mouse hepatocytes (Park et al., 2001). This is the first study to report the absence of significant levels of IL-12Rβ1 and IL-12Rβ2 expression in cultured human hepatocytes. Similar to human hepatocytes, negligible expression of the IL-12 and IL-23 receptors was also observed in human whole liver samples ($n = 3$). However, in PHA-activated peripheral blood mononuclear cells, which were used as a positive control for receptor expression (Desai et al., 1992; Parham et al., 2002; Reddy et al., 2007), mRNA of IL-12Rβ1, IL-12Rβ2, and IL-23R was detected (Supplemental Table 4).

We next examined whether IL-12Rβ1, IL-12Rβ2, and IL-23R expression could be induced in the hepatocytes when exposed to IL-12 or IL-23. Following incubation with 10 ng/ml IL-12, IL-23, or IL-12 +IL-23 for 48 hours, IL-12Rβ1, IL-12Rβ2, and IL-23R expression in human hepatocytes remained undetectable. Similarly, exposure of the hepatocytes to prototypical nuclear receptor activators and known P450 inducers such as β-naphthoflavone (aryl hydrocarbon receptor, CYP1A2), phenobarbital (constitutive androstane receptor, CYP2B6), and rifampicin (pregnane X receptor, CYP2C9, 2C19, 3A4) also did not increase the expression of IL-12Rβ1, IL-12Rβ2, or IL-23R in cultured human hepatocytes.

In addition to IL-12 and IL-23, patients with psoriasis have elevated serum levels of other cytokines including IL-6 and TNF-α (Arican et al., 2005; Takahashi et al., 2010). The IL-6 family of cytokines has been known to affect the expression of IL-6 family receptor subunits, including gp130 (Blanchard et al., 2001). Because of the homology of the IL-12Rβ1 and IL-12Rβ2 with gp130 (Gee et al., 2009), we determined whether either IL-6 or TNF-α would have any effect on the expression of IL-12Rβ1, IL-12Rβ2, or IL-23R. Little to no change in receptor expression was seen after 10 ng/ml IL-6 or TNF-α treatment.

Taken together, the present data demonstrate that IL-12 and IL-23 (individually or in combination) do not alter levels of P450 metabolizing enzymes directly in cultured human hepatocytes. This is likely due to the insignificant levels of expression of the IL-12 and IL-23

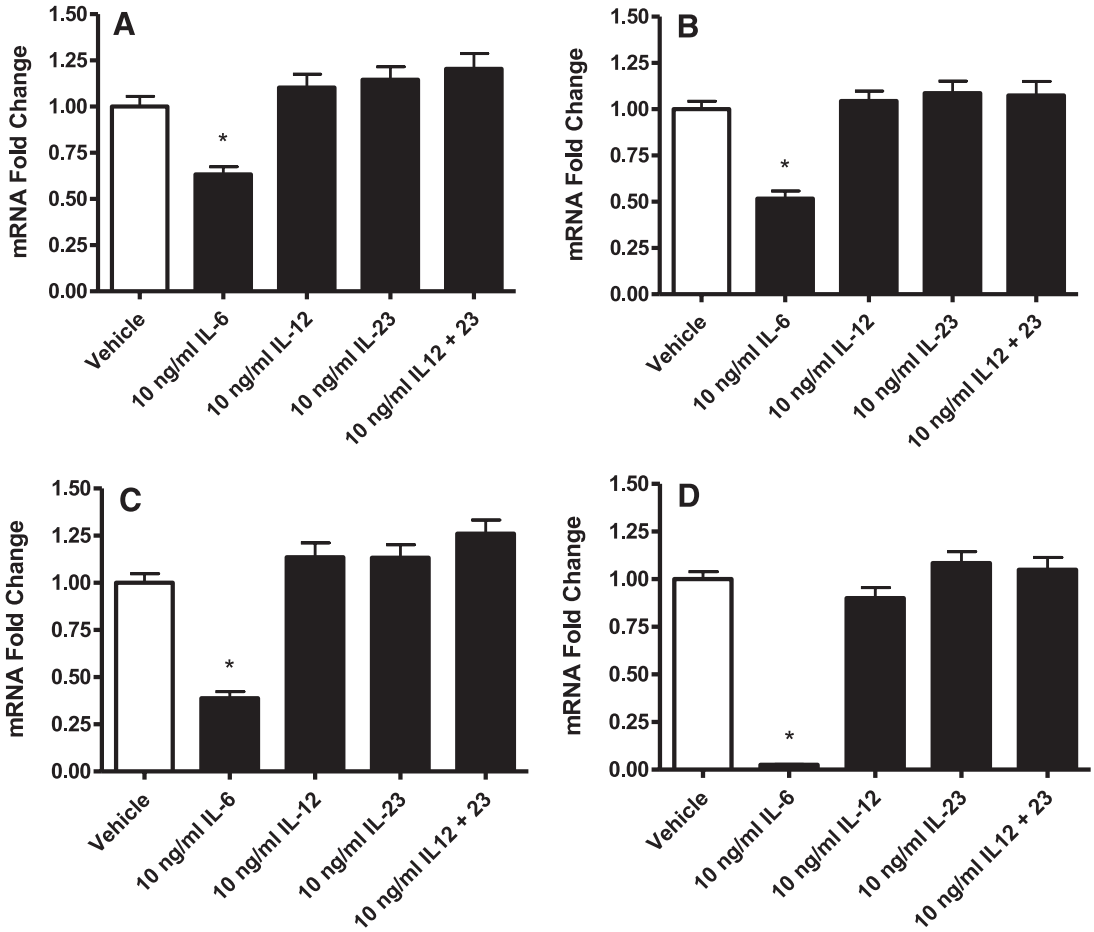

Fig. 2. Effect of cytokines on mRNA levels of CYP2B6 (A), CYP2C9 (B), CYP2C19 (C), and CYP3A4 (D) in cryopreserved human hepatocytes. Six separate lots of cryopreserved hepatocytes were incubated with 10 ng/ml IL-6, IL-12, IL-23, or IL-12+23 for 48 hours. At the conclusion of the incubation period, mRNA levels were determined by RT-PCR. Data points are expressed as mean ± S.E. of experiments performed using hepatocytes from six different donors. $*P < 0.05$ was considered statistically significant.

receptor subunits in these cells. Furthermore, no significant effect on the expression of IL-12Rβ1, IL-12Rβ2, and IL-23R subunits by pro-inflammatory cytokines IL-6 and TNFα was seen. Hence these results suggest that even under inflammatory conditions, IL-12- and IL-23-mediated effects on drug metabolizing enzymes would probably not be observed in human hepatocytes.

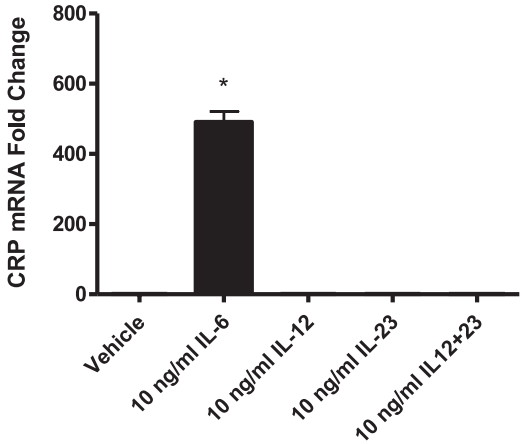

Fig. 3. CRP mRNA levels in hepatocytes exposed to 10 ng/ml IL-6, IL-12, IL-23, or IL-12+23 for 48 hours. At the conclusion of the incubation period, mRNA levels were determined by real-time PCR. Data points are expressed as mean ± S.E. from experiments performed using hepatocytes from six different donors. $*P < 0.05$ was considered statistically significant.

Janssen Research & Development, LLC, Drug Safety Sciences, Raritan, New Jersey

Shannon Dallas
Souvik Chattopadhyay
Carlo Sensenhauser
Ameesha Batheja
Monica Singer
Jose Silva

Authorship Contributions

Participated in research design: Dallas, Batheja, Silva.
Conducted experiments: Dallas, Chattopadhyay, Sensenhauser, Singer.
Performed data analysis: Dallas, Chattopadhyay, Sensenhauser, Singer.
Wrote or contributed to writing of the manuscript: Dallas, Chattopadhyay, Sensenhauser, Batheja, Silva.

References

Aitken AE and Morgan ET (2007) Gene-specific effects of inflammatory cytokines on cytochrome P450 2C, 2B6 and 3A4 mRNA levels in human hepatocytes. *Drug Metab Dispos* **35**: 1687–1693.

Aitken AE, Richardson TA, and Morgan ET (2006) Regulation of drug-metabolizing enzymes and transporters in inflammation. *Annu Rev Pharmacol Toxicol* **46**:123–149.

Arican O, Aral M, Sasmaz S, and Ciragil P (2005) Serum levels of TNF-α, IFN-γ, IL-6, IL-8, IL-12, IL-17, and IL-18 in patients with active psoriasis and correlation with disease severity. *Mediators Inflamm* **2005**:273–279.

Benson JM, Sachs CW, Treacy G, Zhou H, Pendley CE, Brodmerkel CM, Shankar G, and Mascelli MA (2011) Therapeutic targeting of the IL-12/23 pathways: generation and characterization of ustekinumab. *Nat Biotechnol* **29**:615–624.

Blanchard F, Wang Y, Kinzie E, Duplomb L, Godard A, and Baumann H (2001) Oncostatin M regulates the synthesis and turnover of gp130, leukemia inhibitory factor receptor α, and oncostatin M receptor β by distinct mechanisms. *J Biol Chem* **276**:47038–47045.

Christophers E (2001) Psoriasis—epidemiology and clinical spectrum. *Clin Exp Dermatol* **26**: 314–320.

Dallas S, Sensenhauser C, Batheja A, Singer M, Markowska M, Zakszewski C, Mamidi RN, McMillia M, Han C, and Zhou H, et al. (2012) De-risking bio-therapeutics for possible drug interactions using cryopreserved human hepatocytes. *Curr Drug Metab* **13**:923–929.

Desai BB, Quinn PM, Wolitzky AG, Mongini PK, Chizzonite R, and Gately MK (1992) IL-12 receptor. II. Distribution and regulation of receptor expression. *J Immunol* **148**:3125–3132.

Dickmann LJ, Patel SK, Rock DA, Wienkers LC, and Slatter JG (2011) Effects of interleukin-6 (IL-6) and an anti-IL-6 monoclonal antibody on drug-metabolizing enzymes in human hepatocyte culture. *Drug Metab Dispos* **39**:1415–1422.

Gee K, Guzzo C, Che Mat NF, Ma W, and Kumar A (2009) The IL-12 family of cytokines in infection, inflammation and autoimmune disorders. *Inflamm Allergy Drug Targets* **8**:40–52.

Huang SM, Zhao H, Lee JI, Reynolds K, Zhang L, Temple R, and Lesko LJ (2010) Therapeutic protein-drug interactions and implications for drug development. *Clin Pharmacol Ther* **87**: 497–503.

Livak KJ and Schmittgen TD (2001) Analysis of relative gene expression data using real-time quantitative PCR and the 2(-Delta Delta C(T)) Method. *Methods* **25**:402–408.

Luo J, Wu SJ, Lacy ER, Orlovsky Y, Baker A, Teplyakov A, Obmolova G, Heavner GA, Richter HT, and Benson J (2010) Structural basis for the dual recognition of IL-12 and IL-23 by ustekinumab. *J Mol Biol* **402**:797–812.

Kanelleas A, Liapi C, Katoulis A, Stavropoulos P, Avgerinou G, Georgala S, Economopoulos T, Stavrianeas NG, and Katsambas A (2011) The role of inflammatory markers in assessing disease severity and response to treatment in patients with psoriasis treated with etanercept. *Clin Exp Dermatol* **36**:845–850.

Kurebayashi J, Nukatsuka M, Sonoo H, Uchida J, and Kiniwa M (2010) Preclinical rationale for combined use of endocrine therapy and 5-fluorouracil but neither doxorubicin nor paclitaxel in the treatment of endocrine-responsive breast cancer. *Cancer Chemother Pharmacol* **65**:219–225.

Morgan ET (2009) Impact of infectious and inflammatory disease on cytochrome P450-mediated drug metabolism and pharmacokinetics. *Clin Pharmacol Ther* **85**:434–438.

Nestle FO, Kaplan DH, and Barker J (2009) Psoriasis. *N Engl J Med* **361**:496–509.

Oppmann B, Lesley R, Blom B, Timans JC, Xu Y, Hunte B, Vega F, Yu N, Wang J, and Singh K, et al. (2000) Novel p19 protein engages IL-12p40 to form a cytokine, IL-23, with biological activities similar as well as distinct from IL-12. *Immunity* **13**:715–725.

Parham C, Chirica M, Timans J, Vaisberg E, Travis M, Cheung J, Pflanz S, Zhang R, Singh KP, and Vega F, et al. (2002) A receptor for the heterodimeric cytokine IL-23 is composed of IL-12Rbeta1 and a novel cytokine receptor subunit, IL-23R. *J Immunol* **168**: 5699–5708.

Park JW, Gruys ME, McCormick K, Lee JK, Subleski J, Wigginton JM, Fenton RG, Wang JM, and Wiltrout RH (2001) Primary hepatocytes from mice treated with IL-2/IL-12 produce T cell chemoattractant activity that is dependent on monokine induced by IFN-γ (Mig) and chemokine responsive to γ-2 (Crg-2). *J Immunol* **166**:3763–3770.

Reddy M, Davis C, Wong J, Marsters P, Pendley C, and Prabhakar U (2007) Modulation of CLA, IL-12R, CD40L, and IL-2Ralpha expression and inhibition of IL-12- and IL-23-induced cytokine secretion by CNTO 1275. *Cell Immunol* **247**:1–11.

Schmitt C, Kuhn B, Zhang X, Kivitz AJ, and Grange S (2011) Disease-drug-drug interaction involving tocilizumab and simvastatin in patients with rheumatoid arthritis. *Clin Pharmacol Ther* **89**:735–740.

Takahashi H, Tsuji H, Hashimoto Y, Ishida-Yamamoto A, and Iizuka H (2010) Serum cytokines and growth factor levels in Japanese patients with psoriasis. *Clin Exp Dermatol* **35**:645–649.

Torti DC and Feldman SR (2007) Interleukin-12, interleukin-23, and psoriasis: current prospects. *J Am Acad Dermatol* **57**:1059–1068.

Zhang X, Schmitt C, Grange S, Terao K, Miya K, Kivitz A, and Marino M (2009) Disease-Drug Interaction studies of Tocilizumab with cytochrome P450 substrates in vitro and in vivo. *Clin Pharmacol Ther* **85**:S37–S64 Abstract PII-73.

Address correspondence to: Dr. Shannon Dallas, Drug Metabolism and Pharmacokinetics, Janssen Research & Development, LLC, 1000 Route 202 South, Room B104A, Raritan, NJ 08869. E-mail: sdallas@its.jnj.com